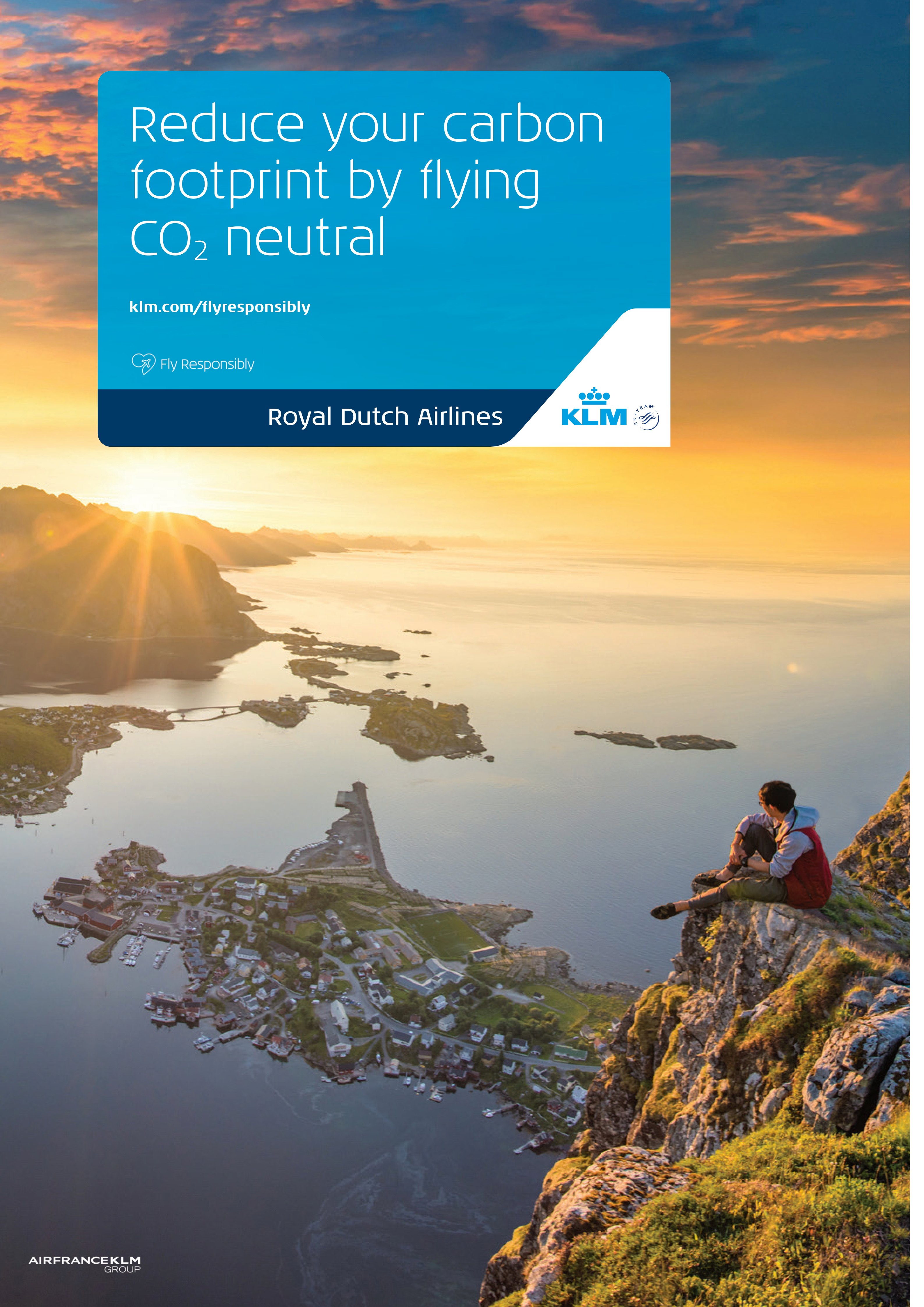
LEONARDO TIMES

Journal of the Society of Aerospace Engineering Students 'Leonardo da Vinci'

CHARGED UP SKIES

NASA's endeavour towards electric flight

Year 25 | N° 2 | Summer 2021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EDITORIAL

Dear reader,

I would like to start with quoting Jeanette Wells – "One benefit of summer was that each day we had more light to read by". This is one of my favourite quotes that embodies the true joy of summertime bloom and sun (another being from a John Mayer song – 'a li'l bit of summer is what the whole year's all about!'). I hope all of you enjoyed a well-deserved break this summer, and to our readers from academia, I wish you a great year ahead.

For us at the LT, the summer issue also marks the end of the academic year, and what a year it has been. With this issue, we wish to highlight an important point of reflection and conversation. After a full academic year of a hybrid, yet mostly online, education model, some interesting and important questions were raised. In this regard, we present to our readers a starting point for a conversation – with an interview article of key personnel at the Faculty of Aerospace Engineering who were involved in shaping the past year's educational environment. We invite our readers to participate in this conversation and hope that a discussion of ideas and perspectives will help shape our collective learning from this experience.

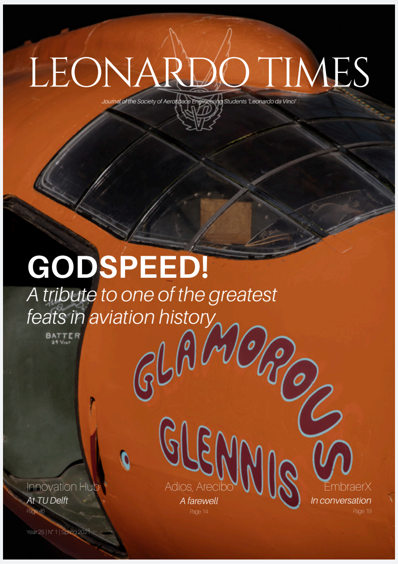
This edition also addresses the need for sustainability across all sectors in the aerospace industry. I hope you will enjoy reading about the strides being made in this regard, with articles on NASA's endeavours as well as conversations with EmbraerX and the GreenTeam here at TU Delft. Lastly, it is our honour to present a candid conversation with the first female aerospace engineering graduate from TU Delft, Ir. Koo Suu Ling. Her experiences not only inform about how her time shaped her journey, but also inspire us to take account of what we can do better to ensure a healthy and an inclusive aerospace industry for women.

I also take this opportunity to write a small note of gratitude for my team. The past year has been an absolute joy working with such enthusiastic editors. The entire year was spent working remotely - something that does not benefit the creative enterprise of putting a magazine together. Yet, everyone rose above and beyond expectations to ensure we got everything done. I will forever be grateful to my team for their support and all that they taught me. As my final order of business, I am really proud to transition the LT leadership to Roosa Joensuu, our new Final Editor, and Ties Rozema, our new Editor-in-Chief. I wish them well, and I am fully confident that the LT will continue to grow and evolve with them.

Concluding this editorial, my last, carries a bittersweet feeling, but I am grateful to you, our readers, who made this experience as enriching as it was. I present to you the Summer issue of the LT. I hope you enjoy reading this issue as much as we enjoyed putting it together.

Warm regards,
Ranjan Gaur

Last edition...



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CONTENTS

26

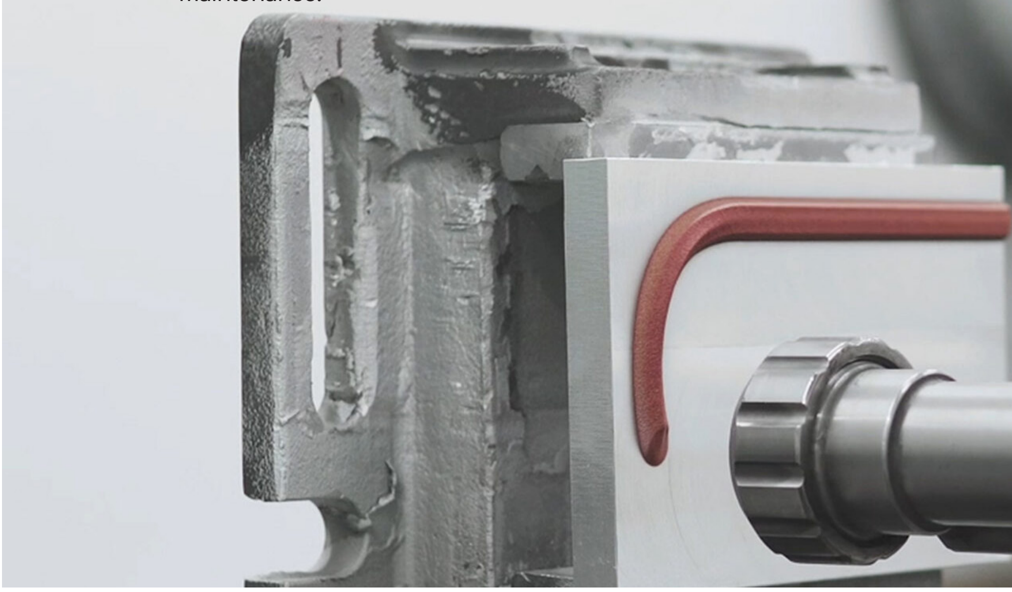
Multi-Beam Optical Communications

To make optical communications more compatible with constellations, taking a deeper look at the design of a multi-beam optical communication terminal.

10

New kit on the block

In this interview experts discuss Gas Dynamic Cold Spraying, a solid-particle spraying process that could disrupt the field of aircraft maintenance.



14

Interview: Ir. Koo Siu Ling

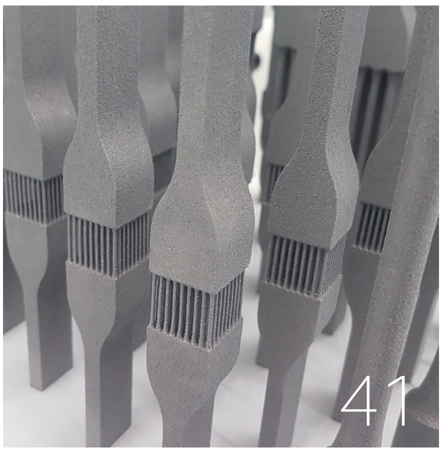
In conversation with the first female graduate from the Faculty of Aerospace Engineering, TU Delft.

Interview: Mr. Daniel Moczydlower

In conversation with Mr. Moczydlower, about his views on urban air mobility and the impact of COVID-19 on the pandemic.

Damage tolerant 3D printing

Can multiple load path structures solve the lack of structural integrity present in current additive manufactured aerospace parts? This study analyses the fatigue and damage behavior of redundant structures.



COLOPHON

Year 25, NUMBER 2, Summer 2021

The 'Leonardo Times' is issued by the Soci¬ety for Aerospace Engineering students, the VSV 'Leonardo da Vinci' at the Delft Universi¬ty of Technology. The magazine is circulated four times a year with a circulation of around 5000 copies per issue.

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On the 30th of June the 76th board of the VSV 'Leonardo da Vinci' had the honour of asking the Dean of the Faculty of Aerospace Engineering, Professor Henri Werij, as member of honour of the VSV 'Leonardo da Vinci'. Already at TNO before starting as Dean, he was enormously helpful, assisting with the organisation of lectures, excursions, and symposia. As dean, even more so now with COVID-19, he has shown tremendous passion in helping students develop into well-rounded aerospace engineers.

A couple days later, on the 2nd of July, another member of honour was asked: Michiel van Dorst, who is the current CEO of LVNL (Air Traffic Control the Netherlands). He started as a young boy watching NF-5s flying over Gilze-Rijen, and he is now at a point where he brings the same inspiration to the students of the VSV 'Leonardo da Vinci'. Over the years, he has helped the VSV out in numerous ways, from CEO interviews to symposia, excursions, and our air show.

Professor Werij and Mr. Van Dorst will be installed by the 77th board of the VSV 'Leonardo da Vinci' at the extraordinary general members assembly in spring 2022.

A MESSAGE FROM THE BOARD

Dear reader,

With seemingly a single blink of an eye, my first foreword in the Leonardo Times has become the fourth, and with this the 76th year of the VSV 'Leonardo da Vinci' is coming to a close. A year, which will be remembered for many to come, and of which the experience gained throughout, will be a distinguishing trait for many of us. With the progress made with the vaccination program, the light at the end of the tunnel comes ever closer, and as the restrictions start to be lifted, the final quarter had many highlights.

In April 2021 the virtual Parents Day took place allowing the second and third year Aerospace Engineering students to show their field of study. Next to this, the new Board of the VSV 'Leonardo da Vinci' was announced, together with the VSV yearbook 'Pioneers' a few weeks before. The month of May was filled with many, lunch lectures, virtual and physical social events where the interview in Delft with Franco Ongaro (ESA ESTEC) was one of its many highlights. In June, the Talk Show 'Aviation Beyond the Pandemic' took place where a diverse group of professionals elaborated on the lessons the aviation industry has learned during the pandemic. And to close the academic year, and celebrate the end of exams, the faculty livestream party Airbase 'Re-Entry' took place before that the Space Department embarked on the Multiple Day Excursion to Luxemburg and Germany!

After the summer break, the VSV will be back to welcome the 440 new bachelor students joining the study, through the yearly Freshman Weekend. Also a group of 20 students will embark on this year's Studytour visiting a wide range of companies within the Netherlands!

Next to bringing you up to speed on some of the activities of the VSV 'Leonardo da Vinci', this edition also contains a variety of interesting articles. Like this you can read about an interview made by Associate Professor Dr. Ir. Gillian Saunders-Smits, with the first female graduate of our faculty: Koo Siu Ling. Or how students reflect on the effect of (prolonged) remote education, as well as the continuation of the interview with Daniel Moczydlower from the previous edition.

To close, I would like to thank everybody who has made this year of the VSV possible, as this will be the last time that I will address you through this manner. It has been a great honour to write these messages, and an even greater one to, through these changing times, lead the society to something that I look back to as a truly successful 76th year of VSV!

On behalf of the 76th Board of the VSV 'Leonardo da Vinci', I wish you a happy read, and we look forward to seeing you at the faculty again soon!

With winged regards,

Jaime Aalders
President of the 76th board of the VSV 'Leonardo da Vinci'

'Space pups' experiment with mouse sperm samples stored in the ISS

A Japanese research team from University of Yamanashi successfully fertilized mouse ovary eggs that spent close to six years aboard the International Space Station (ISS). The research, published in June earlier this year, investigated the effects of prolonged exposure to space radiation on mammals. Radiation can damage the DNA within cells, causing mutations; environments on Earth with heavy radiation exposure, too, can cause defects in mammals.

Space radiation is a major cause of concern for astronauts who spend extended periods of time at Low Earth Orbit (LEO) during missions, and with more active efforts for longer and farther missions in space, this concern is compounded. Previous studies in this regard have been unable to replicate space radiation exposure during experiments on Earth, so this team decided to send their samples in space and subsequently study them. The team sent freeze-dried samples from twelve mice sealed within lightweight capsules. These capsules were stored aboard the ISS for different amounts of time; a portion of the samples were returned to Earth after nine months, some after two years and nine months, and the remaining after five years and ten months. RNA sequencing was used to determine the radiation absorbed by the nuclei and found no significant levels of radiation. The detailed study was published in in Scientific Advances, after the 'space pups' were fertilized and were found to be healthy and with no genetic defects.


TERUHIKO WAKAYAMA/UNIVERSITY OF YAMANASHI

First mission successfully completed by Blue Origins

American billionaire Jeff Bezos's space exploration business venture Blue Origin successfully completed its first crewed mission on July 20th. New Shephard, their vertical-takeoff, vertical-landing, crew-rated suborbital launch vehicle, is named after the first American in space, Alan Shephard. It was a major milestone for both the company and commercial space travel as a whole. Blue Origin also successfully recovered the rocket's reusable booster.

The crew consisted of Blue Origin's founder Jeff Bezos, accompanied by his brother Mark Bezos, 82-year-old space race pioneer Wally Funk, and 18-year-old Dutch teenager Oliver Daemen. The entire mission lasted 10 minutes and 20 seconds from launch to capsule touchdown. Ms. Wally Funk is now the oldest person to have been in space, and Oliver being the youngest. The capsule reached a maximum altitude of around 107km (351,210ft) before starting its descent, parachuting down to a soft landing in the West Texas desert.

BLUE ORIGIN

Jeff Bezos - and other participants in the "billionaire space race" - have been criticised for pursuing what some see as joy rides for the super-wealthy. Critics say the money could be spent on pay rises for employees or fighting climate change. However, Mr. Bezos insists he has an environmental vision: "We need to take all heavy industry, all polluting industry and move it into space, and keep Earth as this beautiful gem of a planet that it is," he told MSNBC.

"It's going to take decades and decades to achieve, but you have to start, and big things start with small steps... that's what this sub-orbital tourism mission allows us to do, it allows us to practice over and over."

Commercial services kicked-off for Virgin Orbit

Virgin Orbit, the company within the Virgin Group which provides launch services for small satellite, kicked off their commercial service after a successful LauncherOne mission on June 30th.

As part of Virgin Orbit's air-launch system, carrier aircraft Cosmic Girl took off from a flight runway at the Mojave Air and Space Port in California. Cosmic Girl, a modified Boeing 747, dropped the rocket at 7:47 a.m. PDT, when it had reached about 45,000 feet in altitude.

LauncherOne separated cleanly and ignited its first stage engine, then completed stage separation. Satellites for the U.S. Department of Defense (DoD), SatRevolution and the Royal Netherlands Air Force, were successfully deployed to 500 km Low-Earth Orbit (LEO).

The mission deployed three cubesats for the US Department of Defense and the Netherlands' first military satellite, a cubesat for Royal Netherlands Air Force called BRIK II, built and integrated by Innovative Solutions in Space. Polish space company SatRevolution launched its first two optical satellites STORK-4 and STORK-5 of the company's planned 14-satellite constellation on the mission as well.

VIRGIN ORBIT

Heathrow Airport Integrates Sustainable Aviation Fuel into Distribution

Under a new partnership with Vitol Aviation and Newste MY Sustainalbe Aviation Fuel, Heathrow airport has begun integrating sustainable aviation fuels (SAF) into its aircraft fuel distribution operations, according to a June 3 press release.The airport hopes to use the new integration as a proof of concept for future fuel distribution at the airport.

"Vitol Aviation's expertise in the specialist handling of jet fuel will be combined with Neste's market-leading SAF production capabilities. Neste MY SAF is produced 100% from renewable and sustainable waste and residue raw materials, such as used cooking oil and animal and fish fat waste. Neste MY Sustainable Aviation Fuel in its neat form and over the life cycle, reduces up to 80%* of greenhouse gas emissions compared to fossil jet fuel use," according the release.

"The UK Government now has an opportunity to create a new British growth industry by backing sustainable aviation fuel production and also be leaders in the race to a net zero 2050," Heathrow Chief Executive Officer, John Holland-Kaye said in the release. "Now is the time for less talk and more action and Ministers should set an escalating mandate to blend SAF into fuel and provide incentives that are stable over 5-10 years to foster investment in production, with a target of 10% by 2030 and at least 50% by 2050."

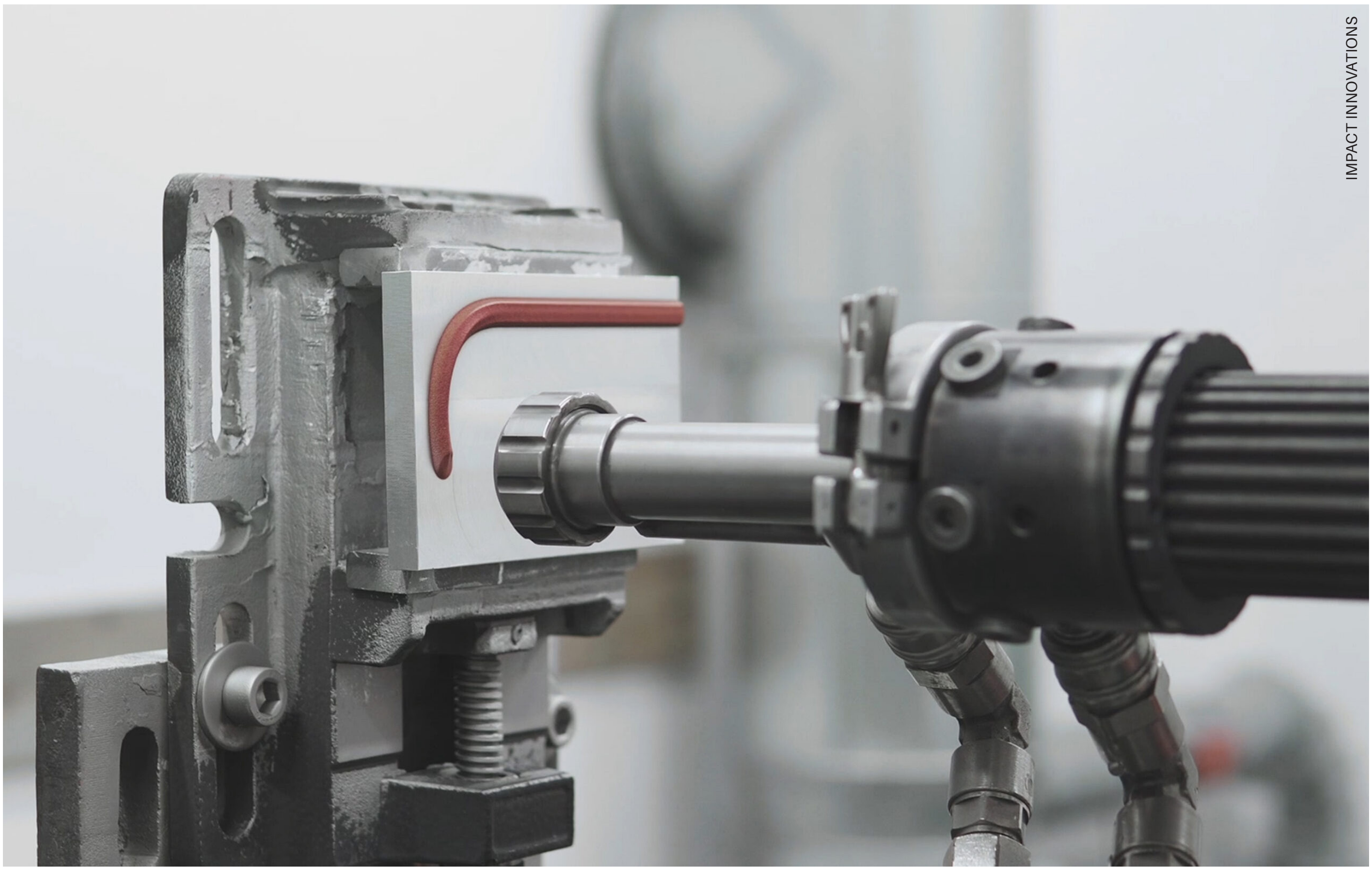
HEATHROW AIRPORT

THE NEW KIT ON THE BLOCK

An interview on Gas Dynamic Cold Spraying

Roosa Joesnsuu, Editor Leonardo Times

ASM



Gas Dynamic Cold Spraying (GDCS) will soon be a 'must-have' process in aircraft maintenance. So, what exactly is it? To answer this question, we interviewed Marcel van Wonderen (KLM Engineering and Maintenance), Dr.ir. John-Alan Pascoe (Faculty of Aerospace Engineering), and MSc student Myron Beukelman (Faculty of Aerospace Engineering).

Let's start with the basics. Could you explain the working principle of the technology?

Everyone: GDCS is a solid-particle thermal spraying process where particles are deposited onto a substrate. It differs from traditional thermal spraying processes because the powder particles are not heated or melted before the deposition. The particle sizes typically range from one to fifty microns. Usually, metal powders are sprayed, but other types of material sprays are also possible. The principle behind this technology is accelerating solid particles to speeds of up to 1200 meters per second through a supersonic De Laval nozzle using overheated gas (as shown in Figure 3). During impact, the particles deform and form metallurgical bonding with the substrate. In theory, a layer of any chosen thickness can be created in this way.

What kind of gases are used for speeding up the particles?

Myron: The idea of a cold spray is to use an inert gas, namely helium, or a mixture of air and helium, or just air. If we only consider the process of making a high-quality coating or material deposit with GDCS, disregarding all economical costs, helium would be the ideal candidate because it is a very low-density gas that easily accelerates to the required velocities. However, current studies mostly look into the use of nitrogen as a carrier gas because it is cheap and widely available. Nitrogen is the way forward.

What are the advantages and disadvantages of this technology?

Marcel: The special thing about this process is that no heat is involved. Therefore, heat does not influence the properties of the material sprayed. This is the biggest advantage of this process. It also means that all heat-sensitive materials can be sprayed. On top of this, the materials are not influenced by oxidation. Many coatings should not undergo any oxidation or have any oxidized products in them.

The velocity and the size of the particles lead to metallurgical bonding of the materials, which form the coating. Another useful advantage is that compressive residual stresses are produced in the coating and on the substrate. The other repair processes used in the aircraft industry, like thermal spraying, plating, machining, and welding processes, result in residual tensile stresses in the parts. One should always see if a process is suitable and will not negatively influence the air-

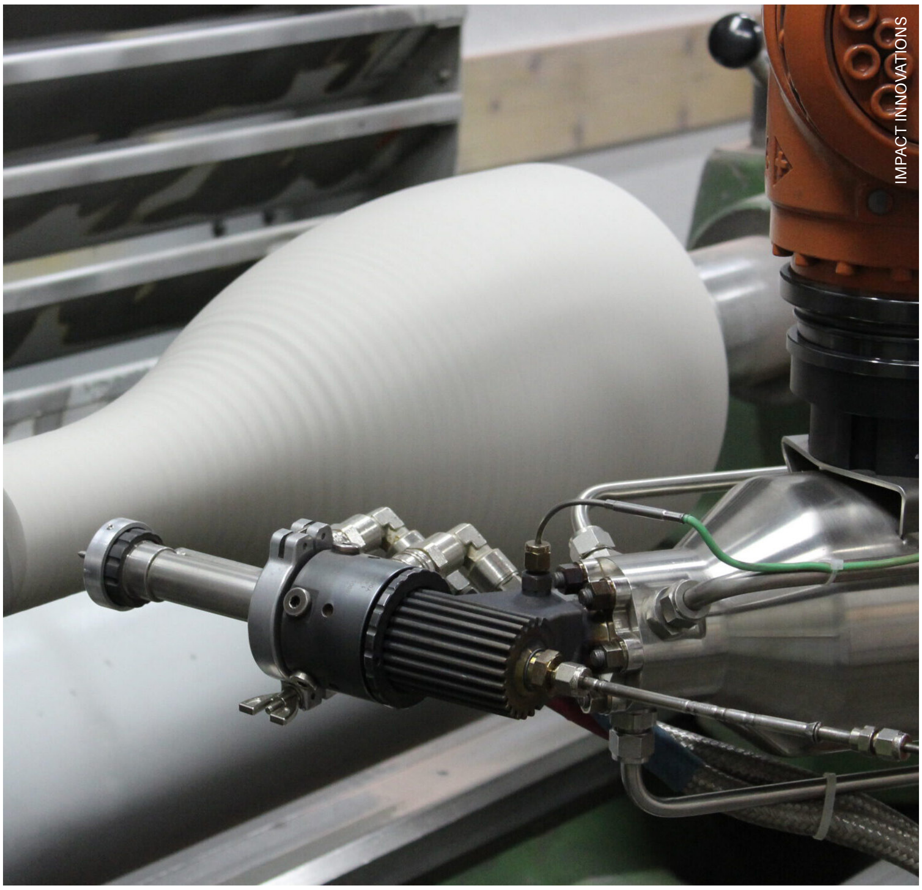


Figure 1: A rocket nozzle produced by cold spray additive manufacturing.

worthiness of a part, because tensile stresses reduce the fatigue life of the parts. Currently, there is only one process in the industry capable of leaving compressive stresses to a part: shot peening. Therefore, shot peening is used as a separate process to compensate or eliminate all the tensile stresses caused by the other processes. Now, for the first time in my career, there is a process, Gas Dynamic Cold Spraying, capable of producing both a coating and residual compressive stress. These stresses are generated by the enormous impact energy of the individual particles causing crystal boundary changes in the base material. The particles will undergo plastic deformation and a kind of diffusion in the base material, resulting in the formation of metallurgical bonds instead of mechanical bonds. That is why none of the disadvantages of thermal spraying or cladding are present in this process. Cold spray is like a replacement of multiple processes in one.

Myron: What it comes down to is that most of the advantages occur from the cold working principles. The powder properties are not lost after spraying. Also, it has already been proven that some of the properties could even improve after spraying. With traditional thermal spraying processes, some powder advantages are lost. Additionally, these thermal spraying processes introduce heat to the substrate. So, for a repair case, these processes are not only influencing the powder properties, but also the properties of the part being repaired! Basically, the repair degrades the material even further.

From the user's point of view, another advantage of cold spray is that very little masking is required, making it time-efficient. It is also more environmentally friendly compared to other thermal spraying processes, which create toxic fumes while spraying. In theory, all of the consumables can be used in cold spraying, avoiding any generation of waste. All the powder that does not adhere to the substrate will fall to the floor and can be collected. The powder is then filtered to ensure that there is no contamination like dust, and can be reused. The same can be applied to the gas: for instance, in a design made using only Helium, a system that recollects the helium used during spraying can be added to minimize waste.

One more advantage is that cold spraying is not limited to spraying the same type of material powder on the same type of substrate. As long as the malleability and other properties of the materials are comparable, different types of materials can be sprayed on top of each other. For example, it is really easy to spray copper on aluminium. During his guest lecture, Marcel showed us that it is even possible to spray metal on glass. I know that there is also research into spraying metallic particles on composites (plastics). There is a whole range of possibilities yet to be researched.

John-Alan: There is enough to do. Something else I saw was a presentation of a cold-spray system that can be loaded on the back of a trailer. The trailer can then be taken into a field where the cold spray repair is done. Of course, a little adjustment is needed, but in general, very little preparation is necessary compared to other processes. Take adhesive bonds, the surrounding environment, like the temperature and the climate, needs to be strictly controlled. However, using cold spray, only a little bit of masking around the edges is needed and the part is ready for spraying. For example, no holes are needed in the material for bolts to go through.

Myron: There is also a cold spraying machine that can be used by hand. Just look at a handheld system, and you already see how easy it is to apply material using cold spraying. Of course, the bigger, more capable systems need a robot and then it becomes a bit more difficult.

Cold spray can also be used in an additive manufacturing set-up, because, in theory, one can build up a layer of infinite thickness. This creates possibility for additive manufacturing with metals. Marcel showed me a company, SPEE3D, which makes complete

3D-printed parts, with cold spray as the main process.

Now that you have mentioned 3D printing, that brings us to our next topic. How does additive manufacturing with the Gas Dynamic Cold Spraying process differ from the repair and maintenance cases?
Marcel: For this particular process, there are several different directions: Dimensional restoration of parts, replacement for thermal spraying or plating, research and development on repairs - presently not possible - but will be with cold spraying. Also, structural repairs, and finally, free-standing bodies, thus additive manufacturing.

Here, structural repairs are something very special. Especially in the aircraft industry, people need to be confident that structural repairs can be done in such a way that the airworthiness of a part will not be influenced or recovered. Of course, we always work with serviceable limits. Normally serviceable limits are based on the present repair techniques, but with cold spray, the present limits can be changed so that repair possibilities increase.

Considering additive manufacturing, the biggest advantage of cold spray over 3D printing machines using lasers, such as DMLS, SLM, LPBF, etc., is the fact that no heat is used. In the laser powder bed fusion, the laser has to melt particles in such a way that it creates a structure. Because of this, the properties of the material in those parts can differ. The quality assurance system must be outstanding: for example, the use of CT scanning to check the results of printed parts is advised. With cold spray, it is already evident that the density is almost equal to the wrought material. Since no heat is needed and the process results in compressive stresses, the chance of producing highly accurate, high-quality standard parts is high. Besides, cold spraying is almost 500-1000 times faster than 3D laser printers. It is a better process practically, commercially, and environmentally. Therefore, it will be a significant competitor for other additive manufacturing processes.

John-Alan: In terms of processing, there is little difference between using cold spraying for repairs or free-standing bodies. With repairs, one would usually have a thinner layer, because the process is used for restoring thinner dimensions but it also depends on the purpose. In dimensional restoration, for example, to print an entire flange, thicker layers are needed. Another aspect is also the kind of substrate to print on; in additive manufacturing, the printed object needs to be removed from the base in the end, but in repairs, it should stick to the substrate.

Myron, your thesis topic is "Gas dynamic cold spraying as an additive repairing method". How did you get into this topic?

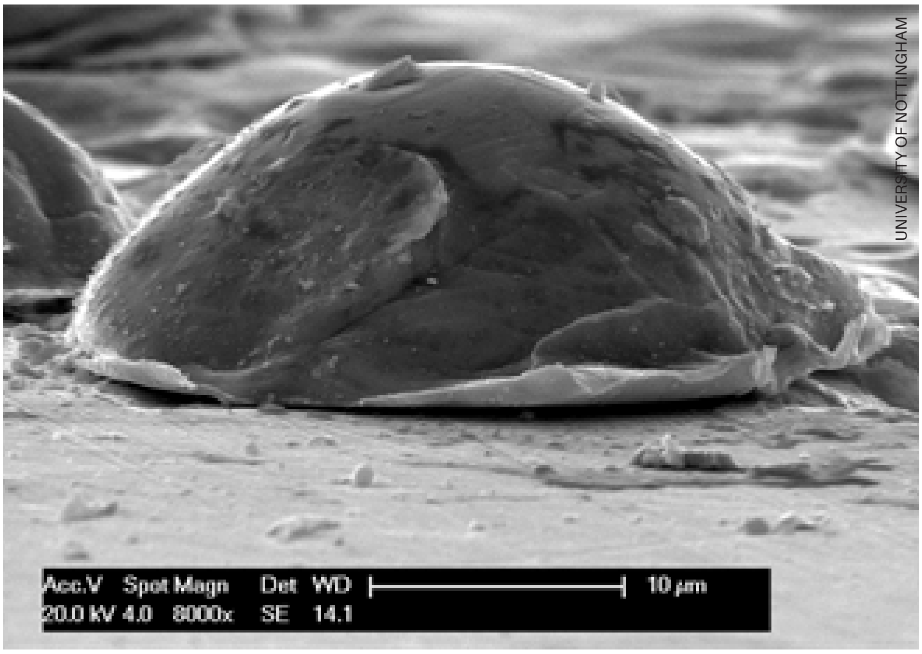


Figure 2 - Titanium particle sprayed onto a steel substrate.

What are the most interesting findings you have made so far?
Myron: Well, I did not find this topic, the topic found me. Last year, I was working on a different topic and I was struggling a bit. I believe that my supervisor, Dr Calvin Rans, noticed this too. One week, Calvin, John-Alan and Marcel had a meeting about cold spraying. The day after, I had a meeting with Calvin, just an informal meeting to see how my thesis was going. He told me about this topic and asked me if I was interested. I had one day to research the topic while I did not even know what GDCS was! I know a lot more now, but within a day, I agreed that I would be glad to work on cold spraying. I am happy to have been given this opportunity, andand I really appreciate that Calvin asked me.

We have already discussed a lot of interesting things in this interview. When I started, the process was completely new to me. I did not know anything about it, and one of the interesting aspects I see in cold spray is that it is repeatable. When you spray with cold spray, you can repeat your results, whereas with 3D printing it is always a question of "will my results be in the same range when I test my samples?", but cold spray shows the same results again and again.

Another very impressive aspect of cold spraying is the relatively simple process; it is just getting the powder up to speed and making it collide with a substrate without any input from heat.

A negative note is that in the whole of the Netherlands, there is only one company involved in cold spraying (Dycomet, in Friesland). They are representatives for foreign companies, and in the near future, they will reveal their own system. I got a chance to be on site and see an actual cold-spray machine working. I read a lot about how it is theoretically possible to achieve an infinite thickness. In Friesland, I saw some very thick sprayed material in real life. If you are handed a cold-sprayed part or item without knowing that it is sprayed, at first glance you would not even recognize that it is sprayed, you would just think that it is cast metal.

Marcel, is KLM currently using cold spraying? Are you planning to expand its use?
Marcel: We do not use the process yet. I have been following cold spraying since 2012. For my work as a process engineer, I attend various conferences around the world to see if there are new innovative processes that could be introduced into the aircraft industry. When I first heard about this process, I immediately saw its potential. Nine years ago, the development was still on a fundamental research level and cosmetic repairs. In 2019, I gave a presentation to the management of the engine services shop to illustrate that this would be an interesting process. The vice-president of the engineering and maintenance division was then convinced this was of interest to KLM. Then, together with Epcor, a subsidiary of KLM, and with engineers from the repair lab, we came up with a business case. Just before the Corona-crisis, we had approval for buying a system. However, due to this crisis, all of the investments were stopped. Now, finally, we are slowly seeing more upward growth. I know for sure that it is not a question of whether we will use cold spraying in our facility, but rather when we are will use this process for our aircraft maintenance, repair and overhaul activities.

Actually, in the United States, there are already parts that have been repaired by cold spray externally, which means that we do fly with parts repaired by cold spray. I want KLM to start using the process, but I also want our country, the Netherlands, to be more involved in cold spray. I think that

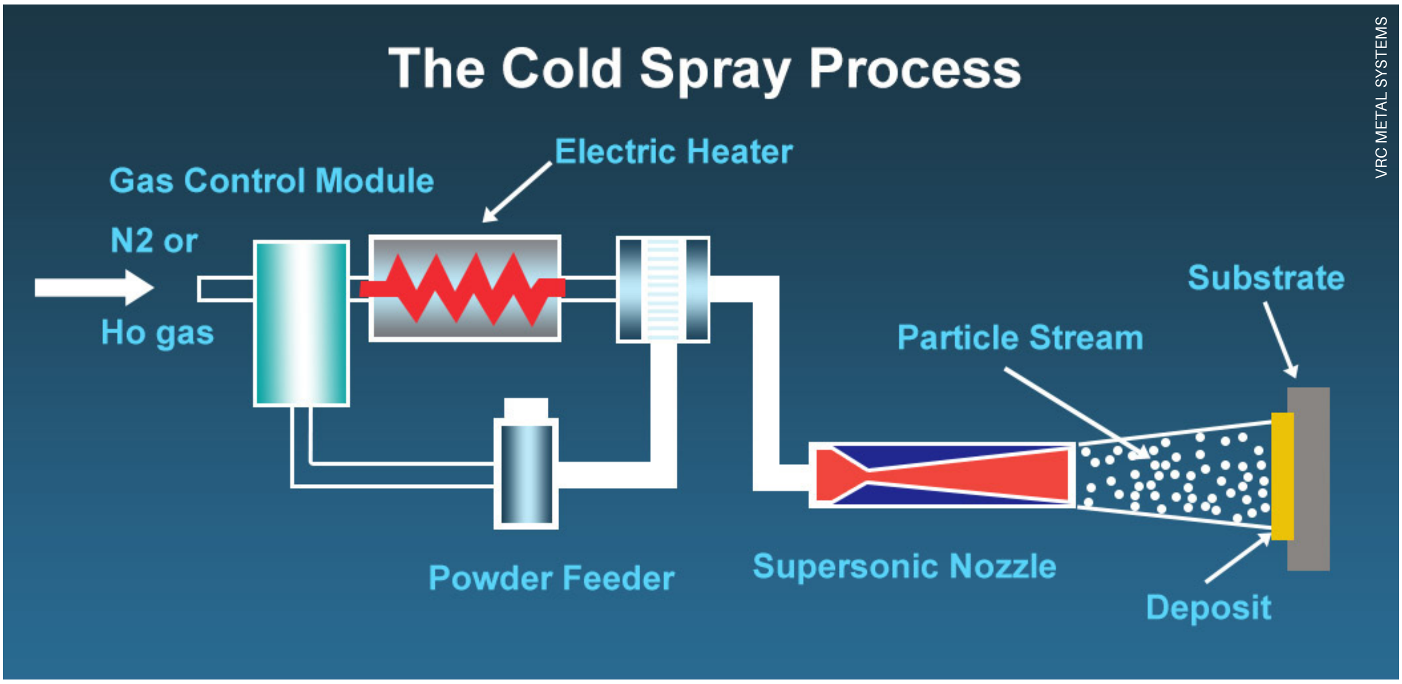


Figure 3 - Overview of the Cold Spraying process.

the Netherlands is far behind the rest of the world regarding this technology. Together with NLR and some other organizations and companies, I will organize a symposium later this year to invite people from the industry to learn about cold spraying.

John-Alan, from the Aerospace Engineering faculty, you are also interested in cold-spraying; what kind of research could be conducted at the faculty?

John-Alan: There are a lot of exciting sides to cold spraying that coincide with various people and their interests. Personally, I am interested in certification, fatigue, and damage tolerance. From that point of view, Marcel already talked about convincing people that a structural repair can actually restore the airworthiness of a part. However, exactly how that can be proved, still requires some development. One thing that can be done is to repair a part and then pull it apart again, to see how strong it was initially. However, this means the part is destroyed, so it is not a good solution.

Every repair is unique to a certain extent - there is varying damage in slightly different places. What we want is a method that people can follow to calculate the properties of the repair to show that it will be acceptable. One angle of research is exactly this - understanding the properties and how to predict them. What can also be researched is the use of artificial intelligence to help repair the parts. Maybe in the future artificial intelligence could be used to manage the process parameters and even to design the repair automatically. It could be similar to a car wash; drive the part in, the machine scans the part, finds the damage, designs the repair, and cold sprays it. Lastly, the part is finished by machining and then leaves the machine again. A lot of research must be conducted to make it become a reality.

Dr.ir. John-Alan Pascoe

Marcel van Wonderen

Myron Beukelman

There is so much interesting research going on and there is definitely room for master students to get involved. We are already looking for the next student to follow Myron. Dycomet is also interested in multi-material printing, combining different materials and maybe creating gradients. If you think more into the future, this could be interesting.

The final question: in what aspects do you think the technology will develop in the coming years?

Marcel: There have already been business analyses that predict that cold spraying will be a 4-billion-dollar market in 2030. Many industries already know the potential of this process, especially because it has a very low CO2 footprint and does not pose occupational health risks. Cold spraying is of commercial interest because of high deposit efficiencies and relatively low-price repairs. It is sustainable, meaning that parts do not need to be replaced anymore, and can just be repaired. The more parts that can be repaired, the lower the energy consumption, and the higher the sustainability index for this process. I predict a great future for this process.

John-Alan: There is a lot of development going into the nitrogen process. As Myron already said, helium gives the best properties, but it is also expensive. It can be recycled, but that makes the set-up more complex because it needs to extract the helium and then be separated. There is work towards making the nitrogen-based processes give as good results as helium. In terms of applications, I think there will be increasing development towards structural applications. The US Air Force has about ten or twenty applications already, but those are all still non-structural. For example, restoring dimensions in places where the remaining part is still strong enough or has a little load to carry. I think the development is there to make the process more structural and will eventually get to primary structures. What is also on the horizon, is additive manufacturing application - really creating new parts using cold spraying, whether it is for a repair or new construction.

Myron: I think there will also be research not only to restore parts to make them airworthy but also to make parts perform better than their original versions. Cold spraying has the potential to improve the performance of parts, to ensure an interesting way forward.

Marcel: I think there is a potential for students at Delft University of Technology to launch new start-up companies in the Netherlands revolving around this process, and now is the chance to do so. ✈

LT would like to thank Marcel van Wonderen, Dr.ir. John-Alan Pascoe and Myron Beukelman for this interview. We are excited to see the developments in GDCS in the future!

INTERVIEW: IR. KOO SIU LING

In conversation with the first female graduate from LR, TU Delft.

Dr. Ir. Gillian N. Saunders-Smits, Associate Professor, TU Delft

Ir. Koo Siu Ling then and now.

"As one of the first women to join the academic staff at the Faculty of Aerospace Engineering, I have often wondered what it would have been like to be the first woman to study aerospace engineering. Who was she? Some of our former professors, fellow students during her study period, had often spoken of her. With a little help from the Internet, I managed to get in touch, and we spoke for a good two hours about her career, her life and her time in Delft."
- Dr. Ir. Gillian N. Saunders-Smits

The first woman to graduate from our faculty, then known as 'Vliegtuigbouwkunde' (Aeronautical Engineering) was Koo Siu Ling. She was an international student of Chinese descent from Indonesia. When she registered to study 'Vliegtuigbouwkunde', it made the newspapers, both in the Netherlands and in Indonesia. She started her studies in 1956 at the age of 16.

Why did you want to study aeronautical engineering?
I really liked the way aircraft looked and how beautifully they fly.

Did you know you were the first woman to study aerospace engineering in Delft?
It was only aeronautical engineering back then, but no, I did not realize there had never been any female students before me. I only learned this when I got to the Netherlands. To me, going to study aeronautical engineering did not seem anything special. The female director of my secondary school was a chemical engineer who studied in Delft, so it seemed a perfectly normal thing to do.

How did your parents feel about you going away to study?
My dad had studied in Rotterdam when he was young, so he was very open to me getting a good education abroad. I had also applied to MIT and was accepted, but my parents felt that going to the United States was not a good idea, so I went to Delft instead.

What was it like when you got to Delft?
Due to family circumstances, I did not arrive

until October 1956 and missed the start of the academic year. I had never been to the Netherlands before and it really took me a while to get settled, find a place to live, buy a bike and so on. I also had to get used to things in the Netherlands. For instance, I had never learned how to make a bed with a blanket on it, or do my own washing. Getting used to Dutch food was also quite a struggle: endive with white sauce and purslane – yuck! Also, living as a boarder was very different than my life back in Indonesia. The house where I rented a room in the attic had no bath or shower, and imagine that you are not allowed to flush the toilet after nine o'clock! I quickly moved out, initially staying with a friend from Indonesia until I was able to move into what was the first dedicated female student house on the Julianalaan.

So, student-housing was already a problem back then?

It was if you were a woman. It probably also did not help that I was not Dutch. Many landlords and landladies did not want to hire out rooms to women, as they often also hired out to men and did not want to have mixed lodgers. At the time there were only 75 female students at TU Delft. We were quickly moved from our student house at the Julianalaan to the Nieuwelaan, as the house at the Julianalaan was to be hired out to male students. The house on the Nieuwelaan is no longer there. The Sebastiaansbrug was built in its place. The bridge goes right through my former room.

What was your first year like?

It was very lonely. Because I arrived after the year had started, I did not know anyone. Initially, none of the other students really spoke to me, it really took a while. During lectures none of the other students would sit next to me or in front of me, even though we had large lectures like Mechanics and Calculus together with mechanical engineering students. At that time, there were only 45 aeronautical engineering students in the first year. As a result, it took me quite a while (1960) to pass my propaedeutic exam.

How did you deal with the loneliness?

Like most women studying in Delft at the time, I joined the 'Delftsche Vrouwelijke Studenten Vereniging' (DVSV – Delft Female Student Association) – we had our own society at the Oude Delft 26 where we ate dinner together every evening. If it was not for them, my life in Delft would have been much harder. I really enjoyed being active in committees and being on the Board. Being involved in DVSV really helped me to get to know people and Dutch customs. The DVSV no longer exists today, it became part of the DSC. That may seem somewhat ironic to some, as at the time there was an unwritten rule ('mores') by the then male-only DSC that the DVSV students should not walk past the front of their building. However, I do like going to the Phoenix society from time-to-time to meet up with old friends.

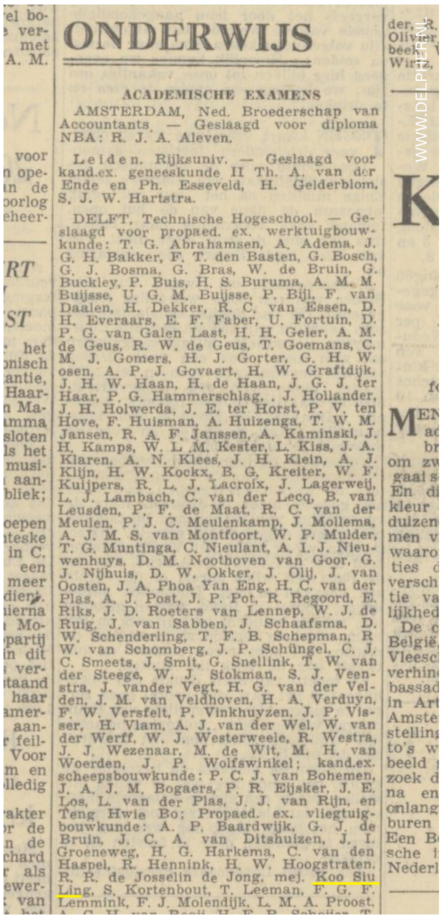
Passing your propaedeutic exam later in your degree was not that strange in those times. In those times binding study advice or MOMI (Modern Migration Policy Act) not exist. Dutch male students did have to be careful about not taking too long otherwise they would get called up for their military service. Passing your propaedeutic exam was considered an achievement and these results were published in the national newspaper, Het Algemeen Handelsblad. (Figure 1)

How did the lecturers and the professors react to you?

They were all very nice and helpful. I was always addressed as 'juffrouw Koo' (Miss Koo). I did need some assistance when in the workshop. At the time, we all had to do metalwork at Mechanical Engineering, and I am not very tall, so I was given a box to stand on so that I could reach the work bench. Similarly, when doing technical drawing: I stood on a stool to be able to reach the drawing board. I did not like technical drawing much. We had to draw using ink and you would always end up with stains on your drawing after using the wing moulds, that you then had to carefully scratch off. Also, the structural analysis course by van der Neut was notoriously difficult.

Funny, that course still exists and is still considered one of the hardest courses by today's students.

Really? I guess some things never change. On the up side, like quite a few students at 'Vliegtuigbouwkunde' at the time, I was allowed to get my pilot's license. I learned to



ONDERWIJS

ACADEMISCHE EXAMENS

AMSTERDAM, Ned. Broederschap van Accountants. — Geslaagd voor diploma NBA: R. J. A. Aleven.

Leiden. Rijksuniv. — Geslaagd voor kand.ex. geneeskunde II Th. A. van der Ende en Ph. Esseveld, H. Gelderblom, S. J. W. Hartstra.

DELFT, Technische Hogeschool. — Geslaagd voor propaed. ex. werktuigbouwkunde: T. G. Abrahamsen, A. Adema, J. G. H. Bakker, F. T. den Basten, G. Bosch, G. J. Bosma, G. Bras, W. de Bruin, G. Buckley, P. Buis, H. S. Buruma, A. M. M. Buijsse, U. G. M. Buijsse, P. Bijl, F. van Daalen, H. Dekker, R. C. van Essen, D. H. Everaars, E. F. Faber, U. Fortuin, D. P. G. van Galen Last, H. H. Geier, A. M. de Geus, R. W. de Geus, T. Goemans, C. M. J. Gomers, H. J. Gorter, G. H. W. osen, A. P. J. Govaert, H. W. Graftdijk, J. H. W. Haan, H. de Haan, J. G. J. ter Haar, P. G. Hammerschlag, . J. Hollander, J. H. Holwerda, J. E. ter Horst, P. V. ten Hove, F. Huisman, A. Huizenga, T. W. M. Jansen, R. A. F. Janssen, A. Kaminski, J. H. Kamps, W. L .M. Kester, L. Kiss, J. A. Klaren, A. N. Klees, J. H. Klein, A. J. Klijn, H. W. Kockx, B. G. Kreiter, W. F. Kuijpers, R. L. J. Lacroix, J. Lagerweij, L. J. Lambach, C. van der Lecq, B. van Leusden, P. F. de Maat, R. C. van der Meulen, P. J. C. Meulenkamp, J. Mollema, A. J. M. S. van Montfoort, W. P. Mulder, T. G. Muntinga, C. Nieulant, A. I. J. Nieuwenhuys, D. M. Noothoven van Goor, G. J. Nijhuis, D. W. Okker, J. Olij, J. van Oosten, J. A. Phoa Yan Eng, H. C. van der Plas, A. J. Post, J. P. Pot, R. Regoord, E. Riks, J. D. Roeters van Lennep, W. J. de Ruig, J. van Sabben, J. Schaafsma, D. W. Schenderling, T. F. B. Schepman, R W. van Schomberg, J. P. Schüngel, C. J. C. Smeets, J. Smit, G. Snellink, T. W. van der Steege, W. J. Stokman, S. J. Veenstra, J. vander Vegt, H. G. van der Velden, J. M. van Veldhoven, H. A. Verduyn, F. W. Versfelt, P. Vinkhuyzen, J. P. Visser, H. Vlam, A. J. van der Wel, W. van der Werff, W. J. Westerweele, R. Westra, J. J. Wezenaar, M. de Wit, M. H. van Woerden, J. P. Wolfswinkel; kand.ex. scheepsbouwkunde: P. C. J. van Bohemen, J. A. J. M. Bogaers, P. R. Eijsker, J. E. Los, L. van der Plas, J. J. van Rijn, en Teng Hwie Bo; Propaed. ex. vliegtuigbouwkunde: A. P. Baardwijk, G. J. de Bruin, J. C. A. van Ditshuizen, J. I. Groeneweg, H. G. Harkema, C. van den Haspel, R. Hennink, H. W. Hoogstraten, R. R. de Josselin de Jong, mej. Koo Siu Ling, S. Kortenbout, T. Leeman, F. G. F. Lemmink, F. J. Molendijk, L. M. A. Proost,

Figure 1 - Propaedeutic Exam results Vliegtuigbouwkunde published on 15 July 1960 in Algemeen Handelsblad Amsterdam .

Koo Siu Ling studente in de vliegtuigbouw

Het aantal aan de Technische Hogeschool te Delft studerende meisjes blijft weliswaar ten achter bij dat van haar confraters; toch wordt het terrein der techniek ook langzamerhand door de vrouw ontgonnen. Dit blijkt wel uit het feit, dat met ingang van het nieuwe studiejaar een studente in de vliegtuigbouwkunde werd ingeschreven; de eerste in de geschiedenis van deze afdeling. Koo Siu Ling is de naam van deze zestienjarige, uit Indonesië afkomstig. Zij doorliep de HBS in Djakarta. Haar vader studeerde in Rotterdam, aan de toenmalige Handelshogeschool.

Figure 2 - Announcement of enrolment in Algemeen Handelsblad Amsterdam on 9 October 1956.

fly in a special version of a Piper Cub where the student could sit in the front as otherwise, I would not have been able to see out or reach the controls.

What about your internship?

That turned out to be a lot harder than I thought. Studying at TU Delft, I did not experience any issues being a woman. Yet when trying to find an internship, I found that engineering firms still held very outdated views on women in Engineering. Fokker Aircraft Company refused me as an intern as they did not want "any women on the work floor". Only through a friend at the DVSV, who was married to someone at KLM, was I able to do my internship there. I found that very disappointing.

What was your specialization?

I specialized in what was known as the 'bedrijfskundige richting' (operational management – now known as Air Transport and Operations, ATO) with professor Spies. After my experiences with the internship, I looked abroad to do my thesis. Professor Taub helped me to find a thesis position with McDonell (known as McDonell Douglas from 1967, now part of Boeing) in the United States.

When you graduated in 1965, it was national news again.

Yes, I even gave interviews to several newspapers. I received my diploma in the new building, which had only just opened. That is the building that still houses aerospace faculty today.

What was next for you? Back to Indonesia?

When I came to Delft that was my firm intention, but the political climate in Indonesia had changed and my parents were no longer living there. Instead, I went back to McDonell Douglas in the U.S. and after obtaining my green card, I started to work in Long Beach California, where I worked on the certification of the DC-9 (Figure 4) at the first part of take-off at different airports. Later, I also modelled take off in slush conditions. That was very interesting as we really had to make well-argued assumptions on the many different variables to make any sort of prediction. I also worked on optimal fleet size calculations. How many aircraft does an airline need to be able to fly all its intended flights and destinations? These were all really complicated multi-variable problems at the time.

Were you also the only woman at McDonell Douglas?

No, not at all. It was much more normal there. My boss at McDonell Douglas was a woman. Again, I don't think being a woman was such a big deal. Whoever you are, you should be able to do what you set out to do and don't let people or things get in your way. If you feel you are disadvantaged, don't just sit and complain, but to get up and do something

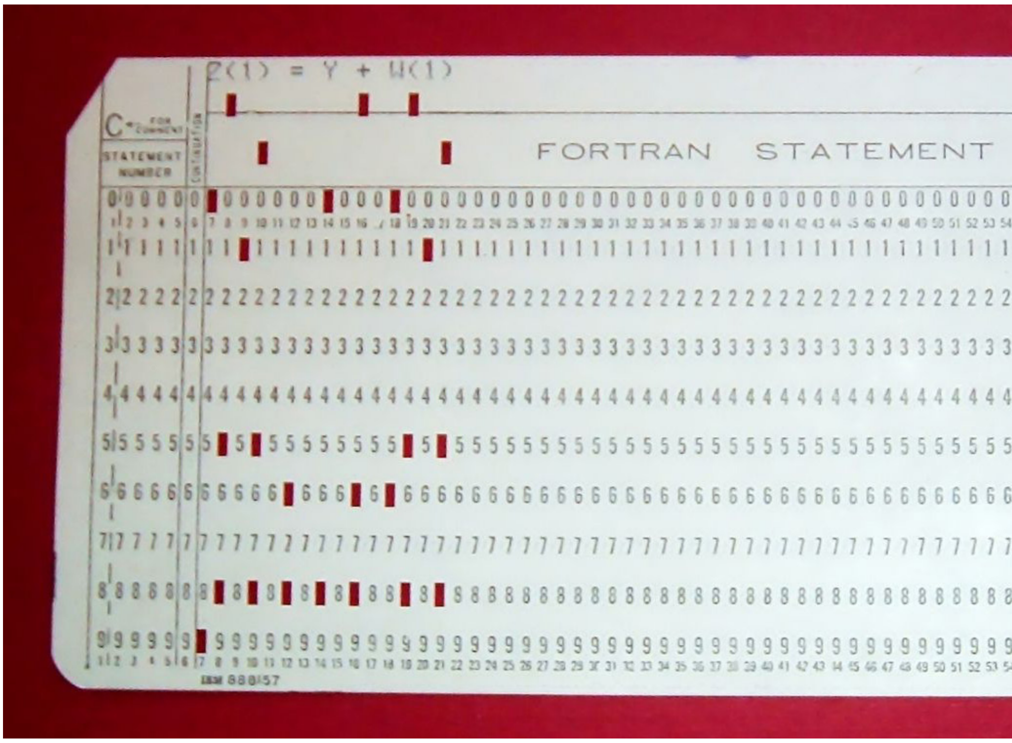


Figure 3 - Right: Punch card from a typical Fortran programme.

about it. That is why I am not in favor of quota for women.

Did your Delft degree help you?

When I got to the United States, I realized that Delft was much behind on modern developments. Everything was done with computers in the U.S. already, and in Delft, we were not taught programming at the time. In fact we did not work with computers at all. Programming was only taught to the Applied Mathematics students. In the U.S. this was already part of engineering programs. There was also a large difference in level of education at the time, it was a big step up and hard work. The U.S. did not recognize our 5-year integrated master's degree as a master's. My diploma was classified as a bachelor's diploma. So, after a few years, I decided to do a master's degree in Systems Engineering at the University of California in Los Angeles (UCLA), next to my normal work at McDonell Douglas.

Learning to code really helped your career?

Yes, and I really enjoyed it too, although Delft provided me with a solid basis in analytical and logical thinking, learning systems analysis really helped me to do my job. In those days, there were no personal computers or laptops. Computers took up an entire room, and you would let it run your program by having the computer read punch cards [1 card per line of code]. You could not write on those cards so you had to be careful not to mix them up. I once fell down the stairs with 2 boxes of punch cards on my way to the computer room. I was not happy that it happened.

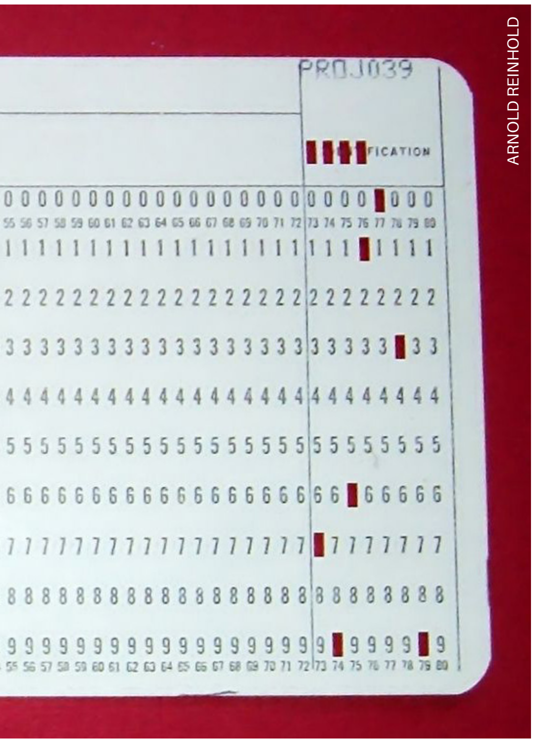
What was next for you?

I married a Dutchman, also an engineer, and came back to the Netherlands. I started to apply for jobs again in the aviation sector, although in principle I did not apply to Fokker after their earlier refusal to allow me to intern. This is where I was again disappointed in the Dutch Aviation sector: The then head of KLM Engineering and Maintenance was very vocal in saying that he wanted as few women as possible working in his department as they would only distract the men. Since then, I avoid flying KLM as much as possible, they don't deserve me as a customer. Instead, I worked at Berenschot, in their IT-consultancy section in system analysis. We moved to Australia for my husband's work, where our children were born. Working and raising a family in Australia was not possible for women back then. When we moved back to the Netherlands, the personal computer had arrived, with which I had to get acquainted. I bought my first computer, a Macintosh.

In the late 70s, Dutch society was not yet geared up for highly educated mothers who wanted to have careers with some flexibility in hours and I could not find a suitable job. However, a friend of mine had started a translating service. She asked for my help in the translation of technical documents, and I helped to translate the first manual for Excel into Dutch. From there, we started a technical translation agency, yet I never became a translator myself. Instead, we hired translators and managed and automated the translation process as much as possible using my engineering and computer knowledge and working procedurally. This led to our company being the only translator agency with ISO certification at the time.

And now? Somehow, I don't think you have quite retired?

No, I am still working on projects. This time in



a whole different direction – I am involved in making books on topics close to my heart. I have published two already, a book on Chinese Ceramics in collaboration with the Victoria & Albert Museum and a cookbook on the Chinese-Indonesian cuisine on Java, based on my mother's handwritten recipe book in collaboration with a professor from Yale University. I am now working on a third book, again on Chinese ceramics.

And in your spare time?

Well, as we are not able to go anywhere at the moment, I am also studying Chinese and, with the blessing that is ZOOM, I stay in touch with my children and grandchildren spread out across the world and keep fit and connected with my friends with ZOOM CrossFit, offered by my gym.

Looking back on your life, would you choose aeronautical engineering again if you had the chance?

That is a good question. In hindsight, I would have probably picked Computer Science, but that degree did not exist at the time. The logic of computing still really appeals to me.

What advice would you give current students?

- Persevere - Understand that not everything is fun right now, but those are the things you won't remember later in life.
- Look around you and keep your eyes open - Don't get too limited in your views by your chosen field. Avoid getting blinders on. During your degree, you often have a narrow view as you don't always have the time to appreciate what is around you.

For International students

If you want to stay in the Netherlands, learn to speak Dutch. It is important to master a local language in order to truly be part of a country. Language is an important tool in your arsenal, also as an engineer! ✈

Figure 4 - A DC-9 - USAir DC-9-31, CC BY-SA 2.0 Aero Icarus from Zürich in Switzerland.

Figure 5 - Man and woman working with IBM type 704 electronic data processing machine used for making computations for aeronautical research at Langley NACA.

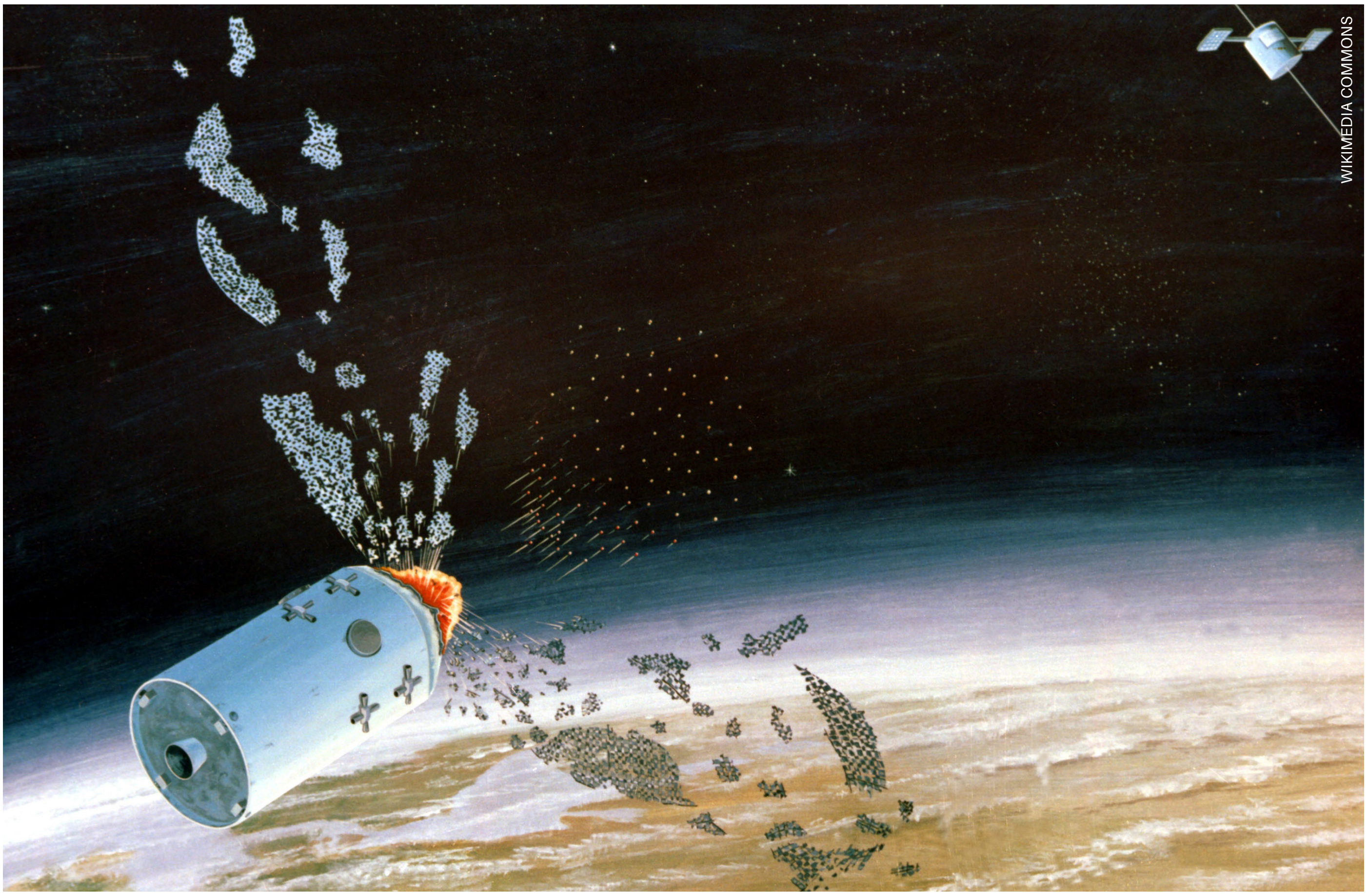
Figure 6 - Interview at graduation in Algemeen Handelsblad Amsterdam, 14 July 1965.

PREVENTING AN ARMS RACE IN

How we can stop a war in the stars

Diego Sánchez de Lerín, Editor Leonardo Times

SPACE



Access to space is similar to the exploration of the seas in the Renaissance. In spite of regulations, the resources required to explore the seas and discover new lands created tensions between European powers. The concept of acknowledging disarmament whilst exploring is not new, but today's circumstances are. As the space race escalated during the Cold War, rules had to be introduced to avoid outer space becoming an area of conflict instead of exercising exploration and research in the interest of all people.

THE BACKSTORY

Less than a year after the Sputnik crisis of 1957, the Western Bloc was immersed in a period of public fear and anxiety due to space weapons and surveillance. Hence, the first set of regulations were setup in 1958 with the founding of the Committee Of Peaceful Use of Outer Space (COPUOS). This was a committee focused on the pacific use of outer space, a loose framework to pursue space exploration for the sake of commerce and peaceful satellite use. Another added objective was to investigate the possible hostile activity.

And yet, public fears were not repelled. It was still thought that activities that come under the purview of the military could easily be disguised as commercial or peaceful ones. Hence, the United Nations intervened in 1967 to create the Prevention of an Arms race in Outer Space (PAROS) resolution [1]. Created in the crux of the Cold War and the space race, PAROS focused primarily on avoiding the proliferation of weapons of mass destruction in space, a task it succeeded in but never managed to evolve from.

For the past fifty years, PAROS has been stagnant. United Nations operates on consensus, extremely difficult to achieve due to the unequal but rising access to space. While transparency and positive confidence-building measures are in force, these need to be accompanied with stronger, legally binding measures if we expect states to act.

A substantial effort towards the restriction to place weapons in orbit was made in 2008 when a draft of the Treaty on Prevention of the Placement of Weapons in Outer Space (PPWT) was made. While the discussions were modernized by applying definitions and ideas not as developed during the Cold War, the draft had mixed reactions by large space-faring nations. Other treaty attempts have taken place since, but the increased complexity and risk associated with space drown their chances of success.

Although a large interest in regulation is apparent, the increased plurality of states' interest in space makes progress difficult. Small

N OUTER SPACE

investigation groups have been created to find new ways to accommodate progress in the form of strategies that PAROS should follow going forward. However, it could be argued that no new regulation is necessary. Tensions globally are not the same as those of the Cold War and war in space is yet to happen.

DO WE NEED MORE REGULATION?

The situation has evolved immensely since the Cold War with the use of outer space not restricted to two major superpowers. The number of players has seen a sharp increase in the last twenty years, be it government or private entities. While no war has occurred in space so far, certain hostile activities, such as signal jamming and dangerous maneuvers, have increased tensions. This is especially worrisome for states relying on their space infrastructure for military activities such as missile guidance systems and communications. This has led to the creation of specialized organizations within militaries, the most famous of which is USA's Space Force.

The creation of space-focused military organizations does not necessarily entail the presence of an arms race. It can be argued that it can only be called an arms race if the reason for the development of armed forces is due to the increased competition and growth within that sector. The greatest danger of an arms race is the snowball effect it can create, and how the said effect can escalate the outcome of rising tensions. It is worth mentioning that the general perception of arms races is deeply related to the events of the Cold War, and that the drivers of competition today, while different, can nevertheless drive the growth of weapons in orbit.

Hence, under current definitions and understandings, it is difficult to ascertain whether the current global situation can be defined as an arms race. As such, UNIDIR (the United Nations Institute for Disarmament Research) proposed a string of indicators that could lead to an arms race [2].

The first indicator is that of *Rivalry*. An arms race is reliant on the existence of tension between states in the form of territorial disputes, cultural influence, and resource-related tensions. Such rivalries already exist, and they have the danger of possibly extending into space.

The second indicator is that of *Corresponding capabilities*. It can be summarized as the purposeful development of the state's military abilities in response to that of other states. This is already taking place, as modern militaries enhance their ability to combat space-based advantages with specialized anti-satellite systems.

Finally, an arms race requires the *acceleration of capability development*, meaning that the rate of increase in military ability increases over time. This is currently the case, as space-based policies are much more abundant now than they were a decade ago.

Under these indicators, an arms race might seem evident. However, some disparities should be taken into account when applying these definitions to the outer space environment. Space warfare would be very different from that of the sea or land, as counter space measures are generally not countered by themselves. Effectively, this means that an anti-satellite missile cannot counter another missile. Perhaps the term 'arms race' is too arbitrary, and additional weaponry in space is not in itself an arms race but just a symptom of the development of space infrastructure. This is meaningful as the increasingly military development of satellites has other uses than that of weaponry, such as increased resilience against debris or guidance systems. The second disparity is that tensions on Earth don't necessarily translate to the deployment of counter space measures. This does require mutual agreements on Earth to avoid conflict in orbit, which is why PAROS exists.

All in all, the ambiguous current presence of a space race is perhaps not as important as how additional conflict can be avoided. It has been speculated that the nature of space warfare lends itself to the development of military countermeasures which can improve stability rather than demand retaliation. Hence, PAROS' role is greater than the control of space weapon initiatives. PAROS must consider counter space measures that can meaningfully destabilize nations in non-destructive ways.

PAROS GOING INTO THE FUTURE

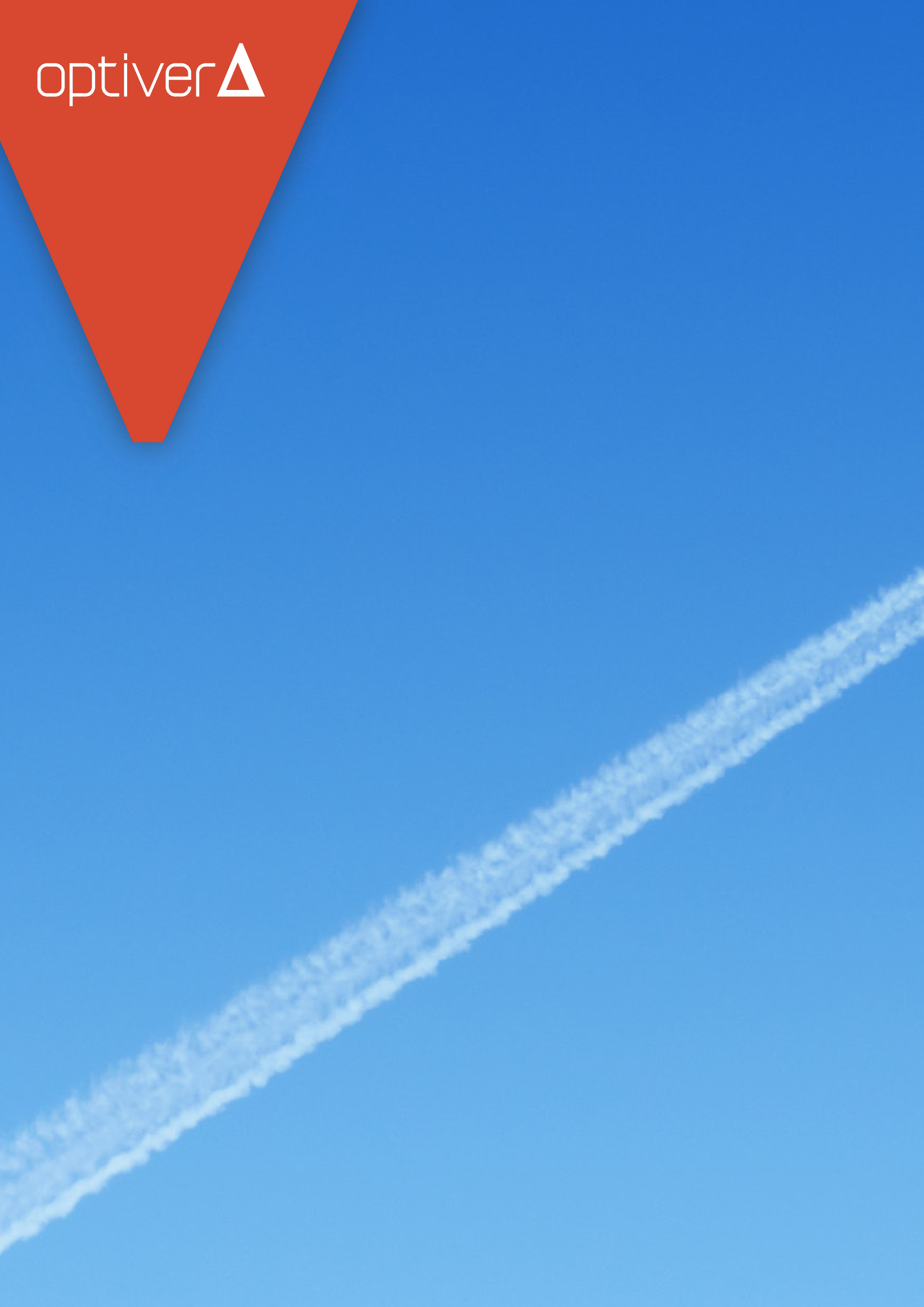
As stated previously, PAROS has had difficulty to reach a legally binding consensus because of its foundation. Moreover, many satellites have both military and civil uses, and states tend to disagree with restrictions that govern the use of space. This is because they do not want to debilitate their commerce on top of their military [3].

What PAROS needs to do to remain prominent in the evolving arms race is redefine what is successful within its field. Given that prevention seems out of reach, ensuring that the military use of space is minimally destructive could have a tremendous impact on future warfare.

Recent developments in PAROS' approach hint at dividing the use of space between destructive and non-destructive segments. Such a distinction leaves room for other hostile activities such as the previously discussed jamming. But these are considerably less harmful than outright destruction as they do not contribute to debris and the target satellite can generally be recovered. By focusing on the destructive capabilities of spacecraft, PAROS can limit its scope and therefore make more meaningful changes in the current trends. However, limiting the scope in such a way is only a temporary measure. As military technology continues to evolve, PAROS must ensure that new kinds of weapons, such as space-to-ground weapons, are also addressed and properly managed.

CONCLUSION

While it is clear that there is a development of states' military activities in outer space, the usage of said activity is inherently associated with conflict on Earth. It is therefore linked to a general increase of military activity rather than one isolated in orbit. Hence, the development of treaties and conventions is unlikely to be fruitful as long as tensions on Earth remain. However, the prevention of the growth of the arms race is not a possibility that should be ignored. States engaged in PAROS can shape how military competition will take place in space, despite being unable to stop it entirely. As such, some of the worst effects of an arms race in outer space can still be avoided.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ARTEMIS: THE NEXT GIANT LEA

On the way to the Moon and onwards to Mars

Joan Ann Mathew, Editor Leonardo Times

SPACE

After almost 50 years since the last man walked on the Moon, NASA is planning the Artemis mission for a sustained human presence on the lunar surface. Several stages of the mission have been charted out to ensure that the next man and the first woman reach the lunar surface by 2024.

The Apollo missions spearheaded the United States' victory in the 'space race' by landing the first man on the Moon and marking an important political milestone in the Cold War rivalries of the 20th Century. As evident from the developments during the World Wars, foreign conflicts were the main motivators behind technological achievements. The successful Apollo 11 mission in 1969 was a culmination of the goals set by President Kennedy and was regarded as a decisive feat in the space race. The next three years saw six successful lunar landings, each bringing back rock samples to Earth. However, soon after, national interest in the missions waned and, due to several reasons, American taxpayers paid more than \$25 billion (or \$156 billion in 2019), against the initial estimate of \$9 billion, for the Apollo program. As the Moon landing had made its mark as a political statement, it was no longer a US government priority to provide significant funding for just research or technology. Hence, manned missions to the Moon were put on hold for the political and economic interests of the country; this is often the case with projects of such a scale.

In the past 50 years, manned missions have seen a renewed interest with the entry of private companies into the sector. In 2017, NASA was asked to develop plans for a human return to the lunar surface, this time with the help of international and commercial agencies. Artemis, aptly named after the Greek goddess and god Apollo's twin sister, evolved as a program to achieve further goals set for the agency: to send the first woman and the next man to the Moon by 2024, to establish a permanent base on the Moon, and to lay out the groundwork for extensive missions to Mars, with the possibility of a human settlement. As opposed to the Apollo missions, the Artemis program is unique in terms of collaborations with the developing commercial space industry in the U.S. and international agencies. As the catalysts for space exploration move beyond scientific research and towards a space economy, the coming decades will see new policies being formulated for the use of lunar and planetary resources. As of May 2021, ten countries have already signed the 'Artemis Accords', bilateral agreements drafted by the U.S. government to lay out laws for mining on the Moon.

SPACECRAFT

The Artemis program is slated to have two major spacecraft: Orion and the Lunar Gateway. The Orion Multi-Purpose Crew Vehicle (MPCV), is a family of partly reusable space capsules: the Crew Module (CM), design by Lockheed Martin, and the European Service Module (ESM), manufactured by Airbus Defence and Space. The Orion system is designed to sustain a crew of six beyond Low Earth Orbit (LEO) and is equipped with solar panels and an automated docking system. As of September 2020, both modules have been assembled and integrated, and have successfully undergone rigorous testing in simulated space environments. The first

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Figure 1 - Pathfinder, the Space Launch System Mock Up arrives for testing of the rocket's core stage at NASA's Kennedy facility in September 2019.

Artemis mission will see the launch of an unmanned Orion into the LEO and further into a lunar distant retrograde orbit. The spacecraft will travel a total of 280,000 miles away from Earth before re-entering at Mach 32. The high speed of re-entry is crucial to test the performance of the heat shield.

The Lunar Orbital Platform-Gateway, or Gateway as it is commonly referred to, is designed to be a space station in lunar orbit that will serve as a habitation module, a communication hub, and a laboratory for lunar missions in the future. Like the ISS, its development is to be actioned by NASA (USA), ESA (European Union), JAXA (Japan), CSA (Canada) and commercial partners; it is also seen as a crucial part in advancing human presence on the Moon and Mars. Crewed missions will begin in 2024 using Orion. The Power and Propulsion Element (PPE) and the Habitation and Logistics Outpost (HALO) will be sent as an assembly aboard SpaceX's Falcon Heavy. The PPE will be a solar-electric propulsion module that will serve as a space tug for incoming spacecraft. The expectation is to generate 50kW of solar power for its ion thrusters. It will also serve as the command and communication center for Gateway. The HALO, also called the Minimal Habitation Module, will be built by Northrop Grumman Innovation Systems and is being designed as an auxiliary module to Orion, with life support systems capable of sustaining a crew of four, for at least 30 days. The ESPRIT (European System Providing Refueling, Infrastructure and Telecommunications) is a service module currently being built by Thales and Airbus. It is planned to have two sub-parts, the Halo Lunar Communication System (HLCS), the communications module, and the ESPRIT Refueling Module (ERM), containing pressurized fuel tanks and docking ports. CSA will provide the Gateway Logistics Modules for refueling and supply, the Airlock Modules, and the Canadarm3, the successor of Canadarm2 presently being used on the ISS. The Gateway has been proposed to extend mission durations, thus reducing risks and providing research capacities due to its location outside the Van Allen belts. It could potentially provide the capacity to reuse ascent modules and is expected to provide operational experience for future missions to Mars.

LAUNCH VEHICLES

The Artemis program will see the use of several launch vehicles developed by NASA, SpaceX, Blue Origins, ULA (United Launch Alliance), and Ariane/ESA. The principal launcher, intended to carry out crew transportation and auxiliary logistics, will be NASA's Space Launch System, or the SLS. With the development that started in 2011, the heavy-lift expendable launcher will replace the now-retired Space Shuttle, from which it is derived, as NASA's primary launcher. The 2-stage launch vehicle will have three variants: Block 1 will be used to launch the Artemis 1, Artemis 2 (crewed), and the Artemis 3 missions. With a payload capacity of 95 tons to LEO, it will use the Interim Cryogenic Propulsion Stage (ICPS). Block 1B will use the Exploration Upper Stage (EUS) as a large second stage with a LEO capacity of 105t. Block 2 will also use the EUS and is intended to have a Heliocentric Orbit (HCO) capacity of 45 tons, with an aim to enable crewed launches to Mars in the latter stages of the program. As of May 2020, the unmanned first flight of SLS (Block1) is planned for November 2021, during which it will carry the Artemis 1 spacecraft Orion along with CubeSats

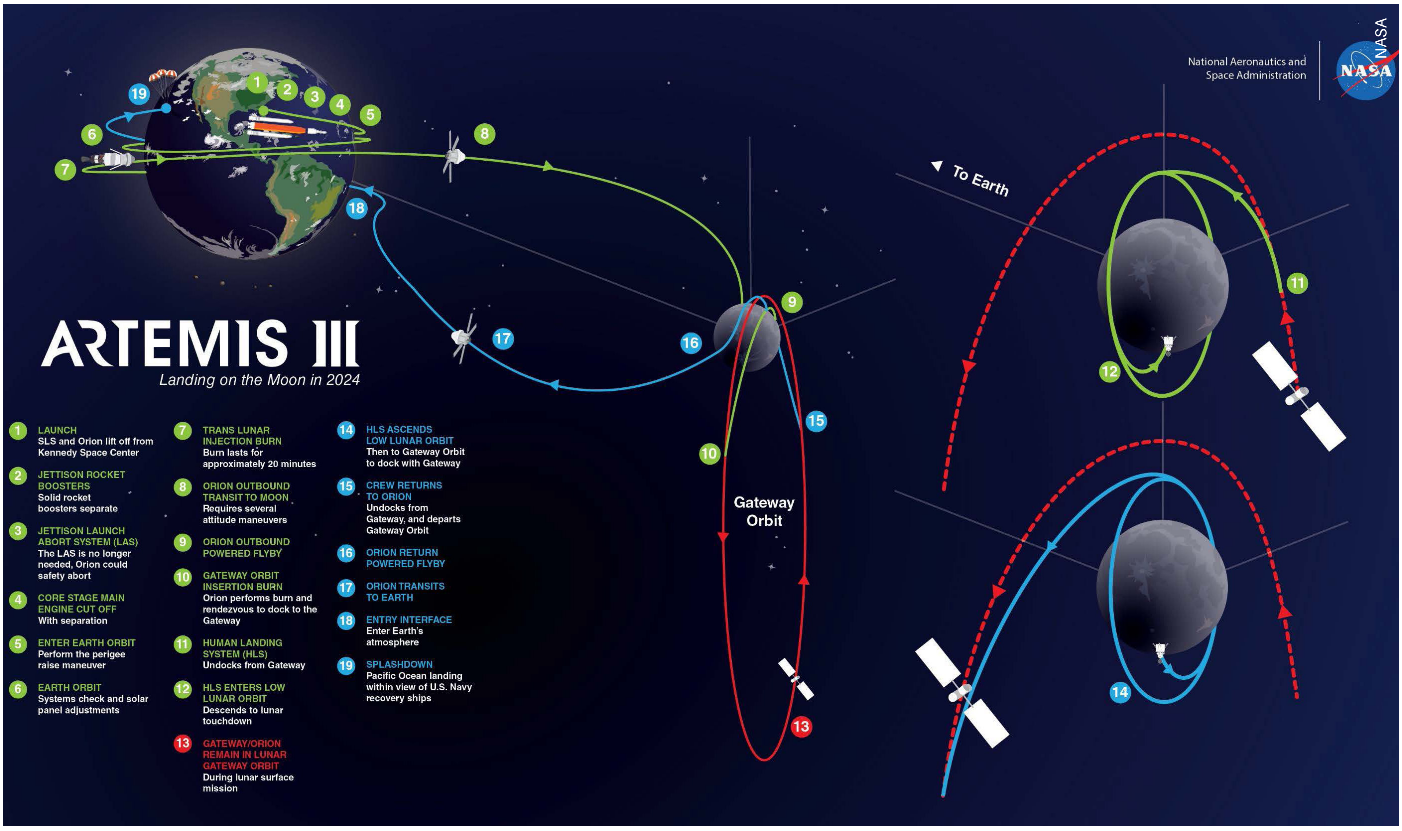


Figure 2- Mission timeline.

on a trans-lunar injection trajectory.

The use of partially reusable launch vehicles by SpaceX set a new benchmark for space programs, and hence the plan of using Falcon Heavy, Falcon 9, and the Starship launchers. The Falcon Heavy will launch the PPE and the HALO modules of the Gateway spacecraft within the program; as of February 2021, the launch date is late 2024. The Falcon 9 family has had 120 successful launches in the past 11 years and will be used for the Commercial Lunar Payload Services (CLPS), a program to transport robotic rovers and landers to the lunar surface. The Starship launcher is a fully reusable (as opposed to the partially reusable Falcon Heavy and Falcon 9) heavy-lift launch vehicle, with an unconventional second stage that will be used as a long-duration crew and cargo spacecraft. It has been contracted by NASA to send a crew to the Lunar Gateway, and as a lunar lander (Starship Human Landing System, or the Starship HLS) from the Gateway in lunar orbit to the surface and back.

The Vulcan Centaur is being developed by the ULA as a heavy-lift launch vehicle that will launch the Integrated Landing Vehicle (ILV) along with CLPS launches. Blue Origins has been contracted to provide two launchers, the New Glenn and the New Shepard, named after space pioneers John Glenn and Alan Shepard. New Glenn will carry modules of the ILV, and the New Shepard will be used as a test launcher for lunar landers. The Ariane 6 is an expendable system in development stages by Ariane Group for ESA. It is slated to launch the ESPRIT, or the European module in the Lunar Gateway, and Heracles, another lunar mission featuring a collaboration between ESA, JAXA and CSA that will feature a lunar lander and a rover.

LANDERS

The Human Landing System (HLS) has been planned as a system to transport crew from the lunar orbit to the surface and back. In September 2020, SpaceX, Dynetics, and the Blue Origins National Team (with Lockheed Martin, Northrop Grumman, and Draper) were awarded contracts to develop landing system design concepts. The final contract decision is due to be announced in August 2021 and increased funding will enable NASA to choose multiple contractors, ensuring performance redundancy. HERACLES (Human-Enhanced Robotic Architecture and Capability for Lunar Exploration and Science) is another lander in the works which will act as a cargo transport system to the lunar surface for robotic rovers, with a payload capacity of up to 1500kg. HERACLES will be used in the primary stages of the Artemis program and will be developed by ESA, JAXA, and CSA.

PROJECT MILESTONES

The initial missions of the Artemis program will start with CLPS deliveries in early 2022 (as of May 2021) launched by SpaceX's Falcon 9 rocket. VIPER (Volatiles Investigating Polar Exploration Rover) is the next mission in the lineup, tasked with researching the distribution of water in the polar regions of the Moon. The following mission will launch the CAPSTONE CubeSat, which will mark the first entry of a craft into the lunar Near Rectilinear Halo Orbit, where the Gateway will be placed. It is expected that the maneuver will improve predictive models about the orbit. The Artemis I launch, the succeeding mission, will see the maiden manned flight of the SLS with the Orion spacecraft to test its heat shield performance. In the next phase, the PPE and HALO modules of the Gateway spacecraft will be launched into lunar orbit to conduct deep-space characterization. Artemis II will be the first crewed mission of the Artemis program, with the ten day test flight aiming to set the record of the farthest human travel from Earth. The NASA astronauts will validate deep space communication, navigation, and life support systems for longer missions in the future. Artemis III is the pioneering mission in the program, aiming to land the first woman and the next man on the lunar surface by the year 2024, using the Human Landing System. In 2020, a group of 12 NASA astronauts graduated from the training program and were assigned to the Artemis Missions. The intention is that two CSA astronauts will join the team, completing the NASA Astronaut Group 22.

ARTEMIS BASE CAMP

While the current design and development phase focuses on the orbital missions, plans have been drafted for the Artemis Base Camp on the Moon. The primary elements consist of the following: Lunar Terrain Vehicle - an unpressurised rover that will transport suited astronauts across sites, the habitable mobility platform - a pressurized rover used for longer trips away from the Base Camp, and lastly, the foundation surface habitat, with the capacity to accommodate at least four crew on the lunar surface and will act as an anchor for NASA's presence at the South Pole of the Moon. Auxiliary infrastructure, along with

Figure 3 -NASA Astronaut Group 22, among which crew will be selected for the Artemis missions.

these modules, is planned to sustain one- to two-month expeditions for research on the Moon, akin to those conducted on the ISS.

Several promising proposals are currently under research to utilize lunar resources, including chemical and thermal processes for converting naturally occurring minerals to human consumables, extraterrestrial mining and construction of habitat modules. Expectedly, policies will be formulated in line with the Outer Space Treaty for the utilization and processing of such resources.

FIRST STEPS ON THE RED PLANET

Post Artemis III, NASA and the partnering institutes' priority will be to gather experience for human missions to Mars through extended orbital and surface missions on the Moon. To ensure that humanity's return to the lunar surface can successfully be converted further into manned missions to Mars, a scalable lunar communications and navigations architecture called the LunaNet has been planned. It will provide a reliable network for bases on the Moon, allowing fast data transfer within the modules. Through the network, astronauts on the lunar base will be ensured of real-time updates on inclement weather conditions without the need for a relay to control centers on Earth. NASA is actively seeking to foster international and private partnerships through these missions and will require this support to develop the LunaNet, analogous to the Internet. Unlike the Apollo missions, where the efforts were unilateral due to political tensions, there is an active endeavor involving multiple space agencies and commercial partners to foster a lunar and Martian economy. The Artemis missions will bear witness to several key firsts in the history of mankind, and, as such, international cooperation is important for a sustained human presence outside planet Earth that will help in the research and technological advancements for humanity.

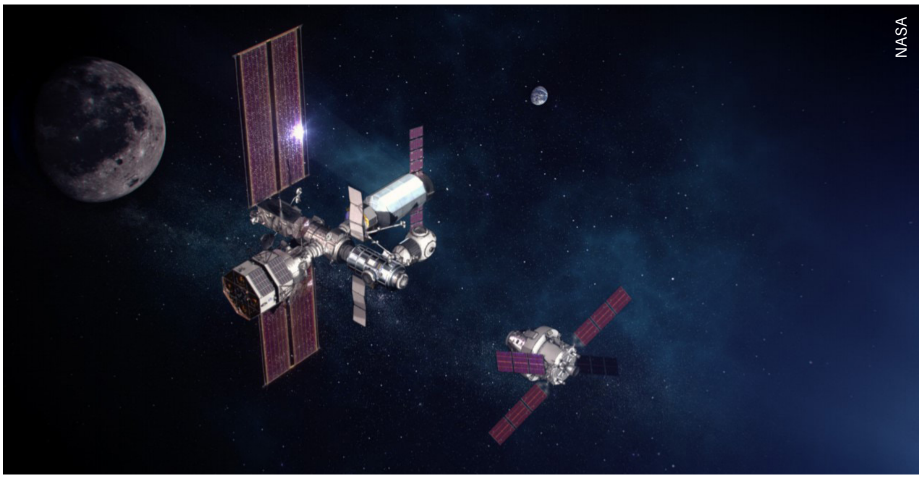


Figure 4 - Artist's impression of the Gateway spacecraft.

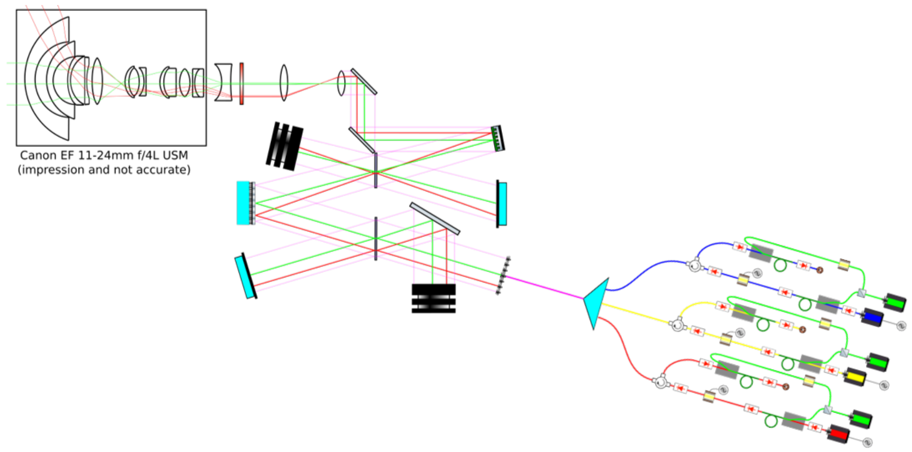
Figure 5 - Artist's impression of the Orion spacecraft.

More information can be found on the Artemis Lunar Exploration Program Overview at nasa.gov.

MULTI-BEAM OPTICAL COMMU

Accommodating more optical links in one terminal

Joshua Spaander, MSc Space Engineering Graduate, TU Delft



JOSHUA SPAANDER

Complete system overview of the multi-beam terminal design. Note that the transceiver is one which uses wavelength division multiplexing [12].

Imagine trying to soak someone you find particularly annoying with cold water. You could try to hit them with a wide sprayer and make sure you have a higher chance of hitting them. However, you would have to get closer and use more water. Alternatively, hitting them with a narrower jet\beam of water allows you to stand back further and more clearly bring across the... message... to the target. This is the advantage of using optical communications.

Optical communication has significant improvements over more traditional radio communications. Using optical wavelengths allow for beams to be collimated in smaller diameters and simultaneously smaller divergence compared to their millimeter radio wave counterparts.

Smaller beam divergence is preferable for many reasons. For one, more power is transferred between the transmitter and the receiver. The reason for this is that more of the signal energy is concentrated on a smaller point. At the cost of increasing pointing requirements, it has numerous benefits to the SNR and subsequently allows for reducing the signal power and increasing the distance between transmitter and receiver. Imagine trying to soak someone you find particularly annoying with cold water. You could try to hit them with a wide sprayer and make sure you have a higher chance of hitting them. However, you would have to get closer and use more water. Alternatively, hitting them with a narrower jet\beam of water allows you to stand back further and more clearly bring across the... message... to the target. This is the advantage of using optical communications.

Privacy is improved as well, where there are less unwanted receivers receiving the signals due to these receivers having to be in the same locations. This has another significant advantage, being that the frequency spectrum does not have to be divided and shared among many multiple users due to these users not interfering. The resulting wide range of bandwidths and modulation options can be used to increase data rates.

The divergence is hence important; however, how much better divergence do optical wavelengths give? This becomes intuitive when considering the familiar and famous Rayleigh criterion or angular resolution:

$$\theta=1.22\,\lambda/D$$

Where θ is the "resolution" angle is the same as the divergence angle of a beam, with wavelength λ, which is diffracted through an aperture with diameter D. It shows that smaller divergence angles can be achieved through using smaller wavelengths. Both radio and visual light are both electromagnetic waves, where radio wavelengths range from 100s of meters to millimeters, starting at long wave radio until microwaves. Optical wavelengths tend to be from about 10s micrometers (μm) to single nanometers (nm). Considering the equation, the order of magnitudes shorter optical wavelengths make for order of magnitudes smaller beam divergences and hence order of magnitudes higher performance.

Radio communication systems attempt to compensate with large dish antennas (which increases the aperture diameter D). However, simultaneously, the diameter of the optical telescope could be a lot smaller for similar results and hence be more suitable for small satellites. In the case of communication with electromagnetic radiation, size matters of the telescope and wavelengths matter.

The contrast between the two technologies can be seen when comparing 2 mass and power estimates for a 10 Mbps system. For a radio system this would imply about 20 kg and 100 W. Conversely, optical terminal would be 0.5 kg and consume 10 W.[1][2]

There are several critical issues with optical communications. A big influence on the communication between stations on the ground and satellite is the weather. Because the technique uses wavelengths (near) visual light, it suffers from the same limitations

NICATIONS

as humans; e.i. it too cannot communicate through clouds and does not deal well with bad weather.

Furthermore, the lack of beam spread also implies multiple targets cannot utilize the same link, not accommodating multiple users. There is another counter side to small beam divergence, namely that it increases the accuracy requirements of the steering systems. This is not only a limitation for the transmitter, however, also on the receiving end requires a steering and tracking system.

The benefit of optical communication is like a double-sided sword. The benefits give rise to quite significant limitations which might significantly hamper widespread adoptions.

Either way the benefits are quite enticing, particularly with the large costs associated with Size, Weight and Power (SWaP). Thanks to the progress in technology, it has made it possible for experiments to be performed for both big and small satellites. The European Data Relay System (EDRS) is a system which transfers or relays data between satellites and ground stations. It employs a laser communication system which can communicate at around 1.8 Gbps to LEO. The satellites which make up EDRS include a laser communication terminal illustrated in Figure 1.

The component layout is relatively straight forward. When considering the path taken by light being received, it first passes a coarse pointer, which points the arm towards the target. It subsequently guides the light into the telescope. The remaining error is then corrected for by a Fast/Fine Steering Mirror (FSM). The light is then subsequently guided through optical elements into the receiver.

The system employs a closed loop control system, meaning that the error in pointing is directly measured and corrected for during operation by a point and track controller. This allows for the system to be more versatile (Figure 2).

NODE, by MIT, is an example of a laser communication terminal for a cubesat. The system can achieve a data rate to ground of about 10 Mbps with future plans of 100 Mbps and can fit into 1.2 U (cubesat volumes being standardised in U's)[2][5][6][7][8]. The system is illustrated in the following Figure 3.

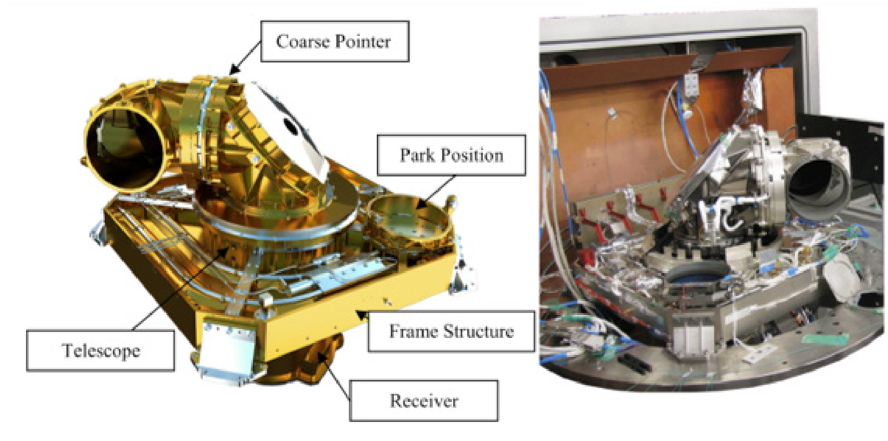


Figure 1 - The optical communication terminal used on the European Data Relay system.

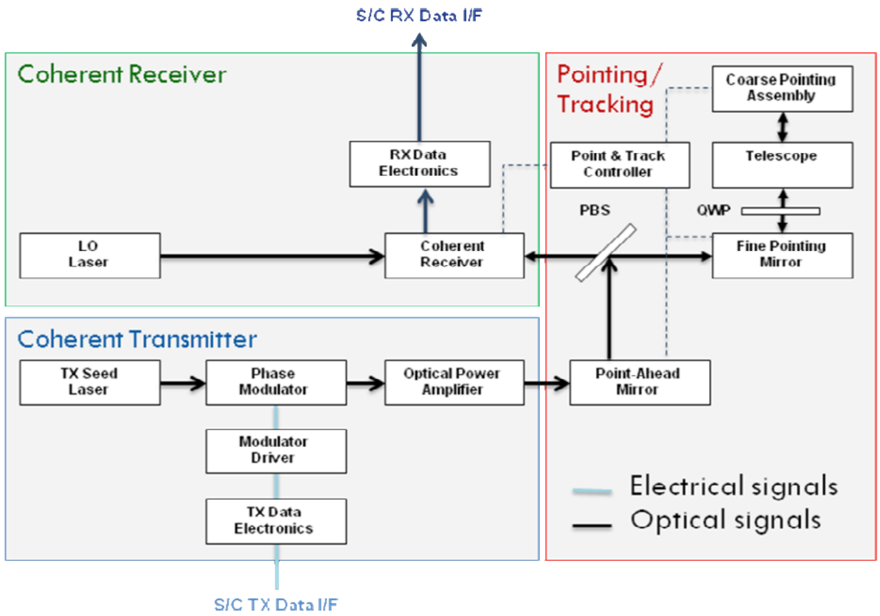


Figure 2 - Block diagram illustrating the system layout and operation of the optical communication terminal used on EDRS. Particularly of interest is the feedback loop from the point and track controller and its interaction with the fine pointing mirror and coarse pointing assembly.[3][4]

This system also indicates a clear way a laser communication system works. Similar to the EDRS system, this system captures light in the telescope which is then steered into the receiver. The coarse pointing in this case is performed by the satellite itself. The beacon indicates the location of the system to the transmitter, while the beacon camera detects the location of the transmitter for the satellite. This system is therefore fundamentally open loop, because the transmitted beam pointing error by the FSM is not tracked. This indicates that an open loop design could also be considered.[2][5][6][7][8]

There are some more drawbacks to optical communications. Namely, that the systems previously described were single beam

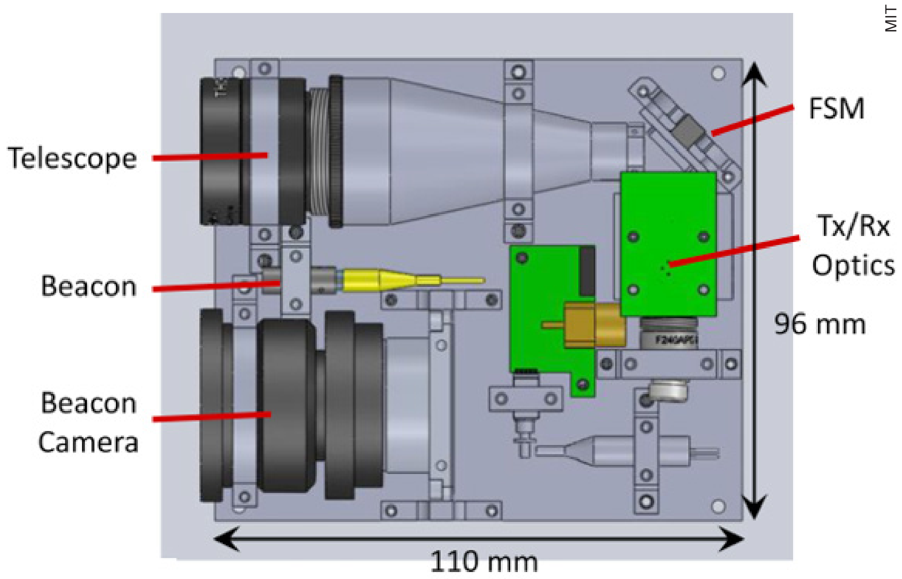


Figure 3 - The NODE laser communication module layout labeled.[5][6][7][8]

Figure 4 - Difference between a curvilinear, left, and rectilinear, right, lens distortions.

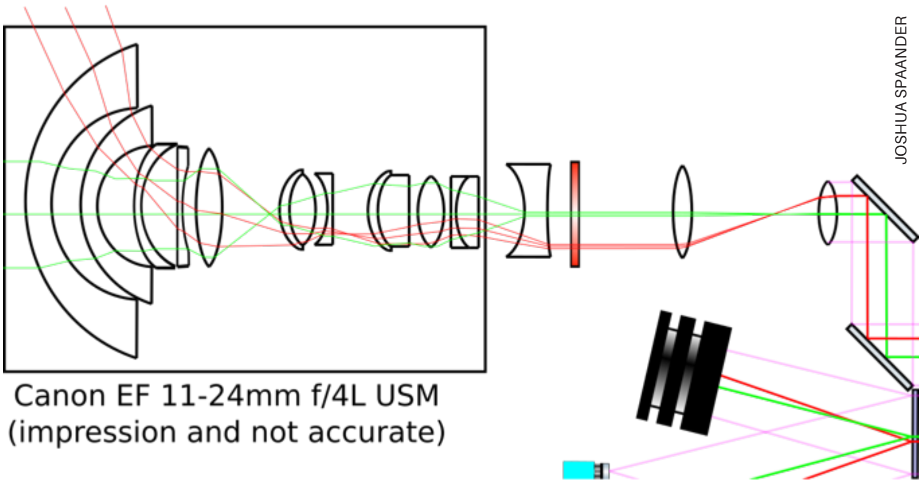


Figure 5 - The design of the telescope and support optics. On the right is the rectilinear lens which brings the beams to optics which parallel the beams. There is a sunlight filter which ensures the system is not destroyed by direct sunlight. Subsequent optics change the size of the beams and guide them into the steering system [12].

Figure 6 - Examples of SLM's [10].

terminals. This limits their ability to facilitate swarms and constellations. Furthermore, it would imply only one ground station can be communicated to at once, making the connection to Earth more susceptible to weather related factors. These drawbacks also stem from the narrow beam benefits.

The goal was hence to design a multi-beam communication terminal which improves on these drawbacks. Being able to facilitate communication between the terminal and multiple targets would increase the utility of optical communication in constellations as well as resilience to weather. Additionally, the multi-beam design must be competitive compared to the single beam designs in terms of SWaP with currently available systems such as the cubesat terminals. The multi-beam terminal would otherwise stand a low chance of being selected over multiple single beam modules. There are multiple ways to achieve this, however, the main ways in which were given special attention to using Commercial Off The Shelf (COTS) components, using single components to handle multiple beams, small scales, high performance and flexibility. Furthermore, the opportunity was taken to explore and potentially improve on a number of aspects.

To design a multi-beam system with application flexibility, the system should be able to handle links in a wide range of directions. This will be referred to as the field of view of the system. To increase the field of view of the system however also forces the designer to start parting ways with single beam designs. The coarse pointing systems, such as the arm on EDRS, would favour one link over the other. A multi-beam system cannot do this because the system cannot point to multiple targets at once and simultaneously share telescope components between them. Hence, the concept of a coarse pointing system as such cannot be included.

Instead, the use of wide angle fish-eye lenses might seem attractive. However, there are severe optical distortions which are created, particularly on the periphery of the aperture, which would distort the beams. The distorted beams have numerous drawbacks, however, particularly when using optic-fiber based hardware. Finding the reason for this will be left up to the reader, however, optic-fiber based communication hardware is the hardware used for the high speed internet on Earth. The allowing it use would allow access to the highest performance COTS components available.
Luckily the choice between fiber-optics and wide angle lenses does not have to be made. The film and photography industry have had problems with image distortion from fish-eye lenses as well and have developed wide angle lenses with limited image distortion. These are called rectilinear lenses. The following image shows the difference between a rectilinear lens and a fisheye lens.

These rectilinear lenses are widely available, however, the optical quality might vary. Due to the true optical quality data for a wide range of lenses not being available, one was selected based on the reported performance. This should be analysed in depth before including the hardware. Some supplemental optics was used to straighten the beams and to filter out sunlight. Subsequently, the beams were then guided into the beam steering portion of the design. The design thus far is shown in Figure 5.

To minimise the number of components, it was chosen to maximise the number of shared components in the optical train. One way which was found to be effective was to use the same path for both the incoming as well as outgoing beams. As a result, steering one would automatically steer the other, implying only half the number of beams have to be kept track of. What more, each steering surface/mechanism steers 2 beams at once per spot, implying that twice the number of beams can be handled as a bonus. Two for the price of one!

There are also some considerations with regards to choosing how to steer the beams. Each target moves through the field of view in an unpredictable way. This implies that the relative distance changes between the beams. Some analysis and optical simulations were done of multiple different steering mechanisms. The two main ones found to be promising were the Spatial Light Modulator (SLM) and the Micro Mirror Array (MMA).

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SLMs are devices which can dynamically change the phase of the light which is reflected off it. This is often done with liquid crystal pixels, where each pixel's effect on the phase of the incident light can be adjusted. The technology is a slight variation on the high resolution monitors used for, among other things, for computers. The result is a large number of pixels (even up to 4k resolution). However, COTS SLM's are also the same speed as monitors. Implying fast jitter might be too quick compared to the response rate of the SLM.

The MMA is an array of small mirrors which are mechanically angled in different ways to steer light. These can be quicker compared to the SLM's, however are limited in their number of mirrors and the space between them. Furthermore, their size is quite a bit

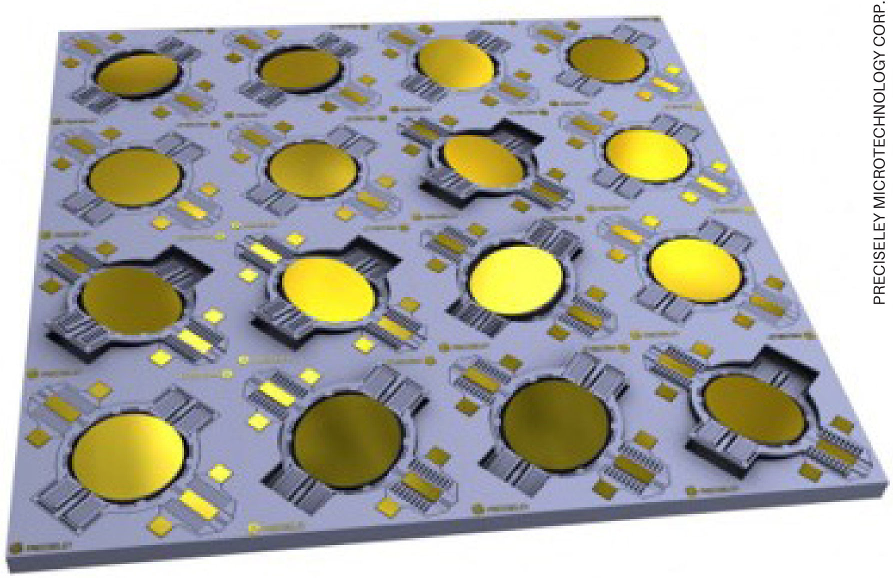


Figure 7 - Example of a MMA. [11]

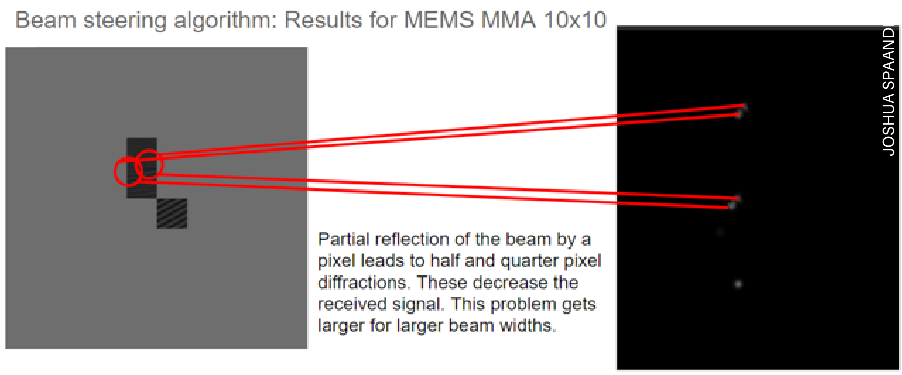


Figure 8 - Illustration of diffraction losses caused by beams interacting with the edges of relatively larger steering surfaces.

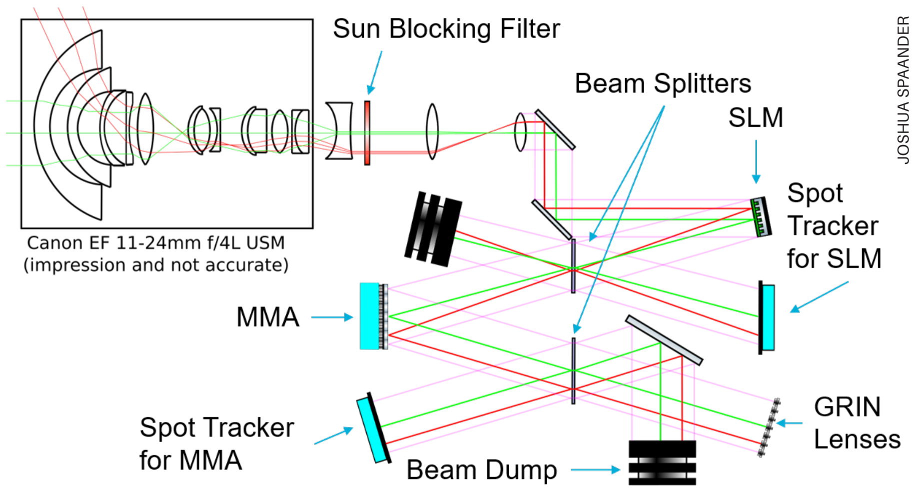


Figure 9 - Overview of all the optics before the transceiver labeled. An incoming beam would start in the top left and enter the rectilinear lens. After passing through the telescope optics, the beams are steered by the SLM's and MMA's into the GRIN lenses. The outgoing beam follows the same path as the incoming beam but in the other direction. Purple indicates the limits of the aperture. [12]

smaller compared to FSMs, making them more attractive in terms of SWaP compared to a relatively bulkier FSM array.

The MMA is an array of small mirrors which are mechanically angled in different ways to steer light. These can be quicker compared to the SLM's, however are limited in their number of mirrors and the space between them. Furthermore, their size is quite a bit smaller compared to FSM's, making them more attractive in terms of SWaP compared to a relatively more bulky FSM array.

From now on pixels, steering surfaces and mirrors will be used interchangeably to refer to steering mechanisms in general. When referring to SLM's and MMA's, this will be done explicitly.

The number and density of steering surfaces, or resolution of the steering mechanism, has an effect on the performance of a multi-beam steering system. Not only does it determine the number of beams which can be steered, but perhaps slightly less intuitively, also affects the data rate. Analysis and simulation of different steering mechanism resolutions found that low resolution steering mechanisms suffer from diffraction losses, caused by the beams being cut in half by a steering pixel. Furthermore, the lower resolutions imply that signals are often lost between targets which are too close together in the field of view. Lastly, having large voids between steering surfaces results in further signal losses.

One such examples of diffraction losses are shown in Figure 8.

The result is that the beams are partially scattered and less signal reaches the transceivers.

As a result, the higher resolution SLM was found to be more optimal at guiding the beams to the transceiver. It is purely this fact that high resolutions would cause higher data rates, longer link uptimes and limit the maximum number of beams by their size and not the number of steering surfaces.

To maintain the same path of incoming and outgoing beams, the angle of the outgoing beams on the transceiver input must be made the same. Here, the beams are already separated and only contain an angular error, removing the need for high resolution steering mechanisms. For this, the MMA was chosen, as having both steering mechanisms incorporated into the design allows for exploiting the best of both worlds. Note, that each steering mechanism contains an independent control loop and can be operated both independently from each other as well as joined.

The control of the beams was designed to be closed loop. The locations of the trans-

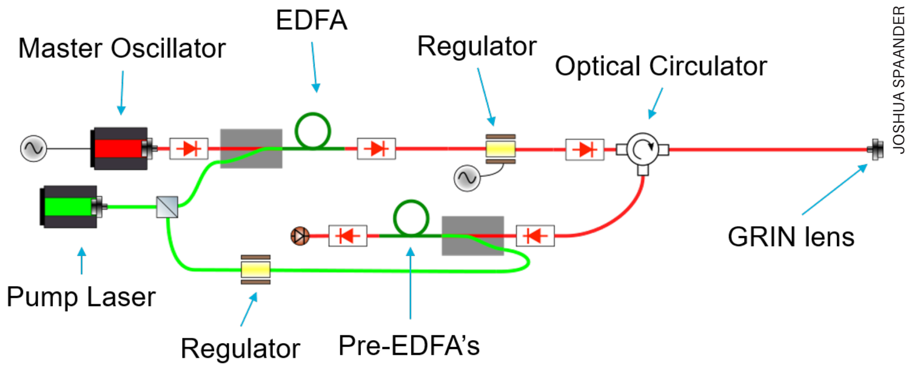


Figure 10 - Labeled diagram of the fiber optics in the transceiver, with the GRIN lens on the right. The fiber between the optical circulator and the GRIN lens is occupied by both incoming and outgoing beams in opposite directions. The optical circulator separates them and sends the incoming beams to the receiver and the outgoing beams are circulated to the GRIN lens from the transmitter. Clearly shown is the MOPA architecture. [12]

ceivers are known, implying that together with incoming and outgoing beams following the same path, only the incoming beams have to be tracked. To track the beams, they are directed to spot trackers.

Spot trackers effectively image the beams as spots onto a camera. These spots are located in the same place as the beams, implying the control system can then use the spots as feedback on the beam locations.

The beams are split with beam splitters and guided to the spot trackers. The trackers were placed at the same optical distance and in the same orientation as the plane where the system wants to steer. So in this case, for the SLM a spot tracker was placed at the same distance as the MMA and the tracker for the MMA was placed at the same distance as the entrance to the transceivers. This keeps the imaged spots as close as possible to the actual situation on the plane and makes for the easiest and more accurate feedback.

To keep the flexibility and utility of the system as high as possible, components which do not affect the polarization were used. However, that implies that the beam splitters split both the incoming as well as the outgoing beams. Since only the incoming beams are used for steering, the split outgoing beams are simply dumped into a beam dump.

The transceiver, as discussed before, was chosen to use optic fiber hardware. Optic fiber has cross sections in the order of 10 μm , making them exceedingly hard to aim for. As a result, a GRIN lens is used to artificially increase the cross section to 1.8 mm.

The design thus far. (Figure 9)
The transceiver design was derived from the previous high performance single beam design. It is fiber based to facilitate same path high performance communications. The design used combines the high performance Master Oscillators with efficient fiber Power Amplifiers in an MOPA architecture. The optical circulator allows for splitting the incoming and outgoing beams in-fiber.

This layout (Figure 10) already implies COTS components used in optic fiber networks on Earth can be used. For a single frequency, this system already performs adequately. However, the performance can be further increased through the use of multiple wavelengths, each modulated with a different data channel and increasing the data rate with a multiple of the number of wavelengths used.

The overall design of a multi-beam terminal is hence quite different compared to the previously discussed single beam terminals. The main difference being the telescope used and the absence of a coarse pointing system. The result is 2 internal steering stages with 2 closed independent feedback loops that steer beams in 3D, to align them with the transceivers. However, in this system, there is no need for beacons and multiple links can be sustained.

The design has a comparable SWaP per link compared to a small single beam cubesat module when handling 5-10 beams or more while maintaining similar performance. This could be too much for many applications. Furthermore, the outgoing beam power is wasted and a significant portion of the incoming signal is lost for beam tracking. However, this was done to increase the systems steering and beam handling capabilities while also keeping the flexibility of the design as high as possible. The system volume implies that the system most likely could not be used on cube satellites smaller than 12 U at the smallest.

However, the design does show that multibeam optical communication terminals made from COTS components are possible and competitive to single beam modules in many applications.

SPACE

NASA GOING GREEN

Innovation in Space and at Home

Topias Pulkkinen, Editor Leonardo Times

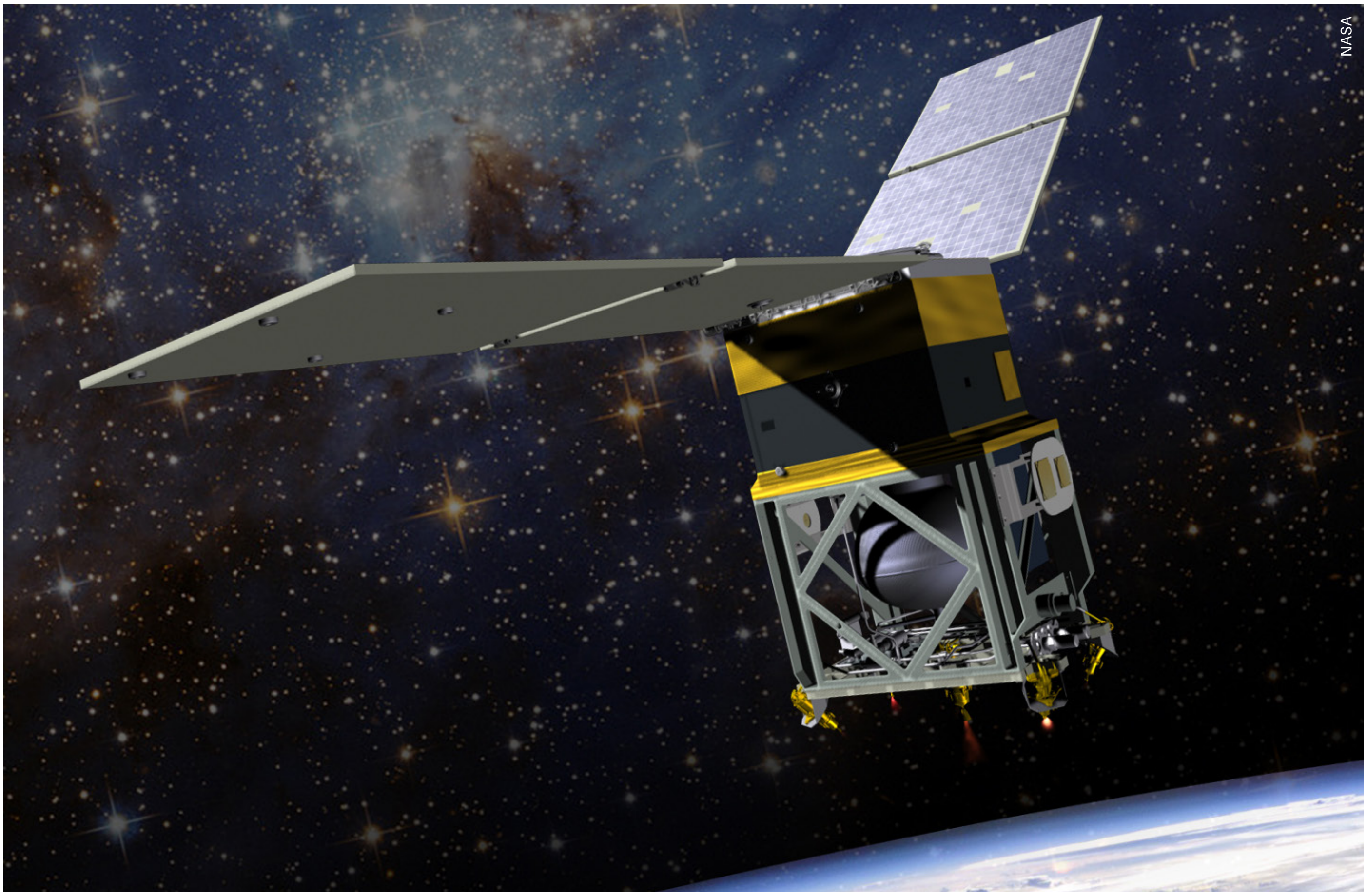


Figure 1 - GPIM satellite in Low Earth Orbit (LEO).

In March 2021, NASA joined the White House National Climate Task Force, bringing more emphasis on sustainability of the agency. The green commitments are not only evident in the agency's missions and research projects, but also in their renewed practices at home.

This article will take a look into some of NASA's most exciting projects and plans in the domain of climate action. Firstly, we will focus on the actions taken in the agency's operations at home (only within the USA), before delving into its work to excel in the fields of space propulsion, earth observations and finally aircraft technology.

On 18th March 2021, NASA officially announced that it had joined the White House National Climate Task Force, an executive order from President Joe Biden [1]. The Task Force states its purpose as the "redefinition of the way government can operate in the face of great crises," according to Ali A. Zaidi, the White House deputy national climate advisor in a statement to the New York Times [2]. The Task Force is comprised of several highly influential government officials, including figures such as the Attorney General, Secretary of Energy and the Director of the Office of Science and Technology Policy [3].

In announcing the news, NASA's Senior Climate Advisor Gavin Schmidt stated "Given our unique ability to observe the planet from space and the long-term data records we've been able to assemble, NASA is in a prime position to inform policy decisions in the current administration and beyond." [1]. Therefore, it may be possible to witness a revamp in NASA's advisory role on climate policy during the Biden Administration, as a perceived extension of the Obama era, when the White House intensely cooperated with NASA on climate policy [4].

The effects of the Climate Task Force on NASA and her operations remain unclear, but the latter did shine a light on some developments in a briefing published on April 22nd 2021. Some new actions that NASA has promised to undertake, include three initiatives to reduce energy consumption and cost. Firstly, with an agency-wide campaign to increase sustainability awareness among employees. Secondly, the agency is beginning to pilot the Department of Energy 50001 Ready program, which requires NASA to "continually improve energy management with quantifiable results" [5]. Thirdly, among approximately 40% of its facilities, the agency has recognized several notable energy users currently excluded within federal energy reduction goals because of their unique

Figure 2 - Boeing-NASA collaboration TTBW.

mission applications. The aforementioned facilities include the ones such as wind tunnels, which boost NASA's investment into cleaner infrastructure. These modernisations are in accordance with NASA's 'Reduce the Footprint' program, which aims to reduce the agency's square footage by 25% to 30%.

Being a space agency, not all of NASA's green transition efforts should solely be implemented on Earth. This has given rise to many innovative missions over the recent years. Some of the most interesting among these are the Green Propellant Infusion Mission (GPIM), which was launched in June 2019 to investigate the feasibility of using hydroxylammonium nitrate as propellant for both launch vehicles and CubeSats, instead of the more conventional hydrazine [6]. This mission was a part of NASA's investigation into propellants which could combust without a separate oxidizer, called ASCENT, short for Advanced Spacecraft Energetic Non-toxic, whose feasibility would make for a huge win for the future of sustainable space travel. Additionally, the mission demonstrated a performance increase of up to 50% when hydrazine was replaced by the hydroxylammonium nitrate, indicating enormous potential for further use. The GPIM did this while providing a greater specific impulse, indicating a more efficient thrust creation process. Moreover, GPIM's material properties prevent it from freezing, instead experiencing a 'glassy transition' at -80 °C [7]. The mission manager, Tim Smith stated "It has the potential to supplement or even replace hydrazine, which spacecraft have used since the 1960s." [8]

Despite its success, within the grand domain of space exploration, the GPIM should only be viewed as an intermediate step for some of NASA's more ambitious plans. For example; the use of ASCENT propellants in lunar missions, like the Lunar Flashlight set to launch in November 2021 as secondary payload of the Artemis 1 Mission [8].

In April 2021, NASA's Perseverance mission also demonstrated the ability to convert carbon dioxide to oxygen, thereby slashing the requirement to take up to 25 metric tons of oxygen from Earth to fuel a returning rocket on its way back from Mars [9]. The large-scale applications of the technology are not yet known. However, the proven viability of a chemical reaction producing oxygen from carbon dioxide certainly brings about some hope, even if the formation of carbon monoxide prevents its use as a means to purify our atmosphere.

Turning our focus back to Earth, the Biden Administration also proposed to boost NASA's earth sciences programs, with an emphasis on the ever-more-prevalent climate monitoring, from the previous $2 billion to $2.3 billion. Yet, this budget must pass Congress before making its dent in NASA's funds. Despite these efforts, NASA's recent chief scientist, Waleed Abdaladi, commented on the increased funding for NASA that "as a result of underinvestment for so many years, it looks better than it is" [10].

Following the launch of the ESA-NASA collaboration in the field of Earth Sciences (named Sentinel-6 in December 2020), NASA released some information on its next-generation climate-monitoring satellites in what the agency calls its 'Earth system observatory', set to provide new insights into cloud and aerosol behaviour. The public should not have to hold their breath for long, as the launch is currently scheduled for 2028 [11, 12] . Although very few details about the missions' exact profiles are available as of 2021, four specialised missions are expected to be part of this project; ACCP (Aerosol, Cloud, Convection and Precipitation), which will mainly measure surface biology and geology, in addition to conducting gravity-field observations due to the disturbances in earth's mass distribution as a result of melting polar ice caps. The ACCP is also set to replace NASA's first attempt at aerosol and cloud behaviour monitoring, the CloudSat and CALIPSO missions launched in 2006. Similar to the previous satellites, the replacing satellites will continue to provide NASA with insights into heat-trapping, albedo and rainfall suppression via the use of aerosols, along with other new technologies. For example, a laser capable of distinguishing between aerosol types, such as dust and smoke, as well as a Doppler instrument set to investigate the 'convective motions that drive storms' [12]. Another new innovation is a high-resolution hyperspectral imaging spectrometer, with the ability to divide reflected light into over 400 wavelength channels across the visible and infrared spectra.

On top of this, NASA is a leading force pioneering in aircraft propulsion with its Advanced Air Transport Technology (AATT) program. This aims to improve energy efficiency and environmental compatibility of subsonic commercial aircraft. This program involves investigating several realms of aircraft performance, such as creating an optimal high aspect ratio wing, reducing combustion NOx emissions and designing a hybrid gas-electric propulsion system. In January this year, NASA partnered up with the American Pennsylvania State University to develop a hybrid-propulsion system to further its sustainability goals in the aviation sector. The partnership came in the form of an $8 million grant, and will target areas in 'additive manufacturing, machine learning and cyber-physical modelling' alongside sustainability [13].

The agency has also dabbled in fully electrified propulsion systems in their Scalable Convergent Electric Propulsion Operations Research (SPECTOR) project, whose brainchild, the X-57 consumes a fifth of the energy of a chemically-propelled jet at its maximum speed of 282 km/h. Yet, the aircraft is still far from meeting global operational requirements - it currently only has a maximum range of 160 km due to limitations in battery capacity [14]. Furthermore, the academic consensus on the viability of fully electric-propelled aircraft is that its use will not begin before the onset of the 2040s, even in the narrow-bodied jet category [15].

On the more commercially viable side, NASA collaborated with Boeing to create an unconventional transonic truss-braced wing (TTBW) design to serve in routes up to 3500 nautical miles or about 6500 km. Compared to conventional aircraft, this provides fuel savings of around 9% - mostly owing to improved aerodynamic features. In the spring of 2020, the design was in its fourth phase of testing and evaluation. Boeing claimed that aircraft using the wing configuration developed in the project could be seen to take off as early as the 2030s. The design, with its unconventional looks, comes with a plethora of even more unconventional perks, such as a 'modified wing sweep and an ultra-thin design, which reduces induced cruise-drag of the high aspect ratio wing' [16]. As an added advantage, the aircraft would have a folding wing, ensuring operational flexibility (more route options to smaller regional airports), thereby competing fairly with narrow-body aircraft, the likes of A320 and Boeing 737 that dominate the market today.

In conclusion, the future for the space agency is looking greener than ever, paving the way for a more sustainable space and air travel going forward. The innovation done in space propulsion by the Perseverance mission will reduce the necessary take-off weight of future rockets by a substantial margin, leading to less fuel burn, snowballing into further weight reductions. At the same time, the agency's ever-increasing ability to observe weather patterns on earth will only improve our understanding on the specifics of climate change. Finally, the innovations done in aeronautical engineering hold the potential to reduce the sector's share of global emissions if implanted in scale on time. Only time will tell if these projects succeed in avoiding the climate disaster.

Figure 2 - NASA's concept of the X-57.

Interview Wessel Wits

Hardware Architect

On the Wednesday after the carnival, which you may know better as the weekend we could all go ice-skating, I met online with Wessel Wits, a Hardware Architect at Thales. I had the opportunity to ask him some questions about what working at Thales is like and how he experiences it. You may know Thales from their location in Eindhoven where they produce cryogenic coolers, but there are many more projects this multinational company works on. However, before we dive in deep, let's start with some general background.

Who is Wessel?

Wessel is an engineer at Thales. But before ending up with such a specialized job, he was a student like all of us. He began his study Mechanical Engineering in 1997 at the University of Twente, after which he did his Master in the specialization of mechatronics. During his study, he had the opportunity to do his internship in Queensland (Australia) and his graduation project was about combining different engineering design disciplines into one design tool. This part of engineering has always fascinated him and so he continued in this field of expertise later on.

" Thales is a good fit between in-depth research and industry development"

How did you end up at Thales?

After graduating at the UT, Wessel surely wasn't done there yet. He was asked for a PhD project in which he could work on optimizing antenna designs to enable cost benefits of mass production. As you might have guessed, this assignment was supported by Thales, so that's when he first got in touch with the company. During his PhD, he already worked in the head office in Hengelo for some days a week. This even resulted in him being the first Dutch engineer to receive the Thales PhD price in 2010 for the best PhD research within the Thales organization worldwide!

After his PhD, Wessel decided to remain at the UT, where he could work on his research and teach Mechanical Engineering students courses on engineering design. While being Assistant Professor, he set up his own research line not surprisingly with topics close to

Thales' interests, such as thermal management. This included research on how new technologies, like 3D printing, could be used in this field of engineering. While doing so, he mentored quite some students for their graduation project, many of them doing projects at Thales.

After almost 15 years of working for the UT, Wessel decided it was time for something new. After a 6-months sabbatical at NLR (Netherlands Aerospace Center), he was invited by Thales to work as a Hardware Architect. They were looking for an outsider however with experience and knowledge of the company, which made him the perfect candidate. So, finally after being in close contact with Thales for a long time already, as of 2018 Wessel became an official employee.

Could you give a general description of your function?

As Hardware Architect, Wessel holds an interesting position. He works at the Mechanical and Electrical Engineering department, where he has two roles. On the one hand, he is hardware architect for several projects, which means he is responsible for the design of new products, how they can be fabricated and how they meet customer requirements. On the other hand, Wessel is responsible for implementing new technologies and processes into the department: an interesting challenge! Take for instance hot topics like Industry 4.0, artificial intelligence or 3D-printing. These techniques have been hyped for the last couple of years in academia and industry, but how can they be implemented effectively?

Why would someone want to work at Thales?

With all the research experience Wessel already has, he found that Thales is a good fit between in-depth research and industry development. With about 30% reinvestment of annual sales into R&D, this is no surprise. This results in high-tech systems and developing products that are the best of the best. Furthermore, all fields and discipline within Mechanical Engineering are applied in Thales projects, from heat and flow to mechatronics and structural analysis, and from design to production and logistics. Since everyone has their own kind of expertise, you learn a lot from other colleagues on the job while deepening your own area of expertise.

Because Thales is a multinational company that has facilities worldwide, there are possibilities to work abroad as well. Although Wessel mainly talked about radar systems they develop in Hengelo, Thales has many other fields of expertise as well. In the Netherlands alone, you can also find departments for cybersecurity, communication systems or cryogenic coolers for instance.

Are you curious what Thales could offer you? here are many internships, graduation projects and vacancies which you can find at

DELFT HYPERLOOP

Diego Sánchez de Lerin, Editor Leonardo Times

DelftHyperloop 05 pod shell.

Ever since entrepreneur Elon Musk announced his concept of a novel transport mode, the Hyperloop, a concept combining the speed of air travel with the convenience of trains, the idea has struck a chord with engineers globally. To further develop the idea through the minds of young talents, the Student Hyperloop Competition was formed.

DEALING WITH COVID

TU Delft is a proud epicenter of many student initiatives participating in various competitions around the world, better known as Dream Teams. However, the past year has not been like any other ordinary one. The pandemic has had a tremendous effect on all Dream Teams - the Hyperloop Competition is no exception. The traditional competition had to be replaced altogether and will now be hosted by the European Hyperloop Week, starting on July 19th 2021. With the move from California to Spain come new organizers, new rules, and new criteria. Delft Hyperloop 05 (DH05) is excited to prove that their design is the best in all six categories: mechanical, propulsion, levitation, electrical, complete pod, and full-scale.

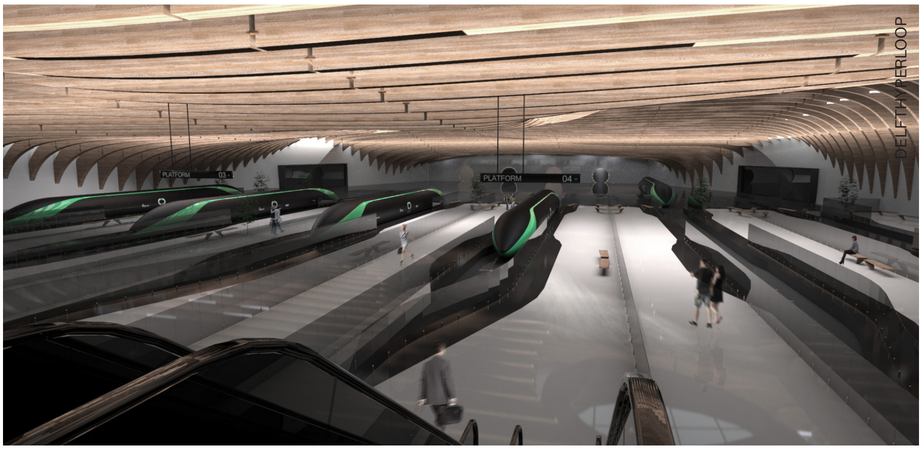
Historically, Delft teams have been known for placing great focus and consequent inputs on the concept of Hyperloop as a whole, rather than simply trying to attain top speeds, which is just the mindset to potentially achieve great success in the upcoming competition. This year's 39 member-strong team with departments allotted for each individual subsystem as well as a scalability team. This is in addition to the mandatory management and business teams required to make the team work and grow together. It is a Dream Team strategy which has been well tested and proved true, with the additional twist of an entire department focused on the big picture of Hyperloop, and how it can be implemented in modern society.

Winning these competitions is not just a proof of technical expertise; planning and managing a large team is an immense challenge, owing to the fact that the pandemic has continued to rage on, for the entire year. The team commenced with only 12 members, as uncertainty regarding the competition made it particularly difficult to assemble a team large enough to tackle such a large-scale project. Madeline Zhang, one of the Sense & Control engineers of the team, was asked about her experience as one of the early-joining members.

Members had to be very versatile, as the workload was immense and design decisions still had to be made. Roles had a broader sense than they are now, with members being distributed in technical and managerial positions. Diversity in the team composition was a great asset early on, as many members were international, new to Dream Teams, or new to Delft, or all of the above. While these could be seen as detrimental, a warm welcome and common ground as ambitious engineers helped turn unfamiliarity into a benefit. Diverse opinions and working methods led to a set of decisions that defined DH05, and as a consequence, turned out to be the most ambitious Delft Hyperloop project since its creation five years ago.

New members arrived throughout the first few months, with the team almost complete by December 2020. At this point, the initially broader roles could be turned into specialised roles, such as Propulsion Engineer or Partnerships Manager. But even with a complete team, it was quite an unconventional experience; meetings were mostly held online, which allowed the team to save their commuting times. However, when you're working with new technology on extremely short deadlines, good communication and team bonding are invaluable assets.

The team came up with multiple clever solutions to this problem, largely thanks to the team's engineers. Notably, they sacrificed time to properly plan fully regulation-compliant, safe, socially-distanced, in-person team meetings. As simple as it may sound, spending time and effort to plan such meetings while complying with regulations was extremely valuable. Seeing your co-workers can give a lasting impression of how they work, what they enjoy, and what they may require help with. At the end of the day, they are still students. Although the talent displayed



Hyperloop station concept by DelftHyperlop.

Elon Musk with the Delft Atlas01 team.

is impressive, most of them are new to the environment and require support, especially during a pandemic. A specific Microsoft Teams channel was created solely to tackle these individual problems that can arise. The members felt heard, and help was even provided for simple tasks like moving some crates.

THIS YEAR'S NEW TECH

Overall it is apparent the team managed to create strong bonds despite the situation. This surely helped them when designing the pod – it is intrinsically different to all previous ones, and those it will compete against. The team took a gamble this year, and they chose to use a propulsion system unique to their project in the form of a Linear Synchronous Motor (LSM). Everyone else has used and is using a Linear Induction Motor (LIM).

Thus far, Linear Induction Motors have been favored in student competitions due to their relative simplicity and the fact that they tend to accelerate faster. The latter point proved to be vital in previous competitions, as the prize was awarded for the highest top-speed attained within a given short distance. LIMs work essentially like a typical motor, but one that is spread throughout a track rather than in a closed loop. Like a rotary motor, one part generates a varying magnetic field which generates a force in a conductor. These motors allow for high accelerations due to the avoidance of energy losses and few moving parts.

However, the team chose to indeed opt for a Linear Synchronous Motor. This method avoids creating a force through an induced magnetic field altogether, and instead relies on creating a force by placing permanent electromagnets on the track which are pushed from behind and pulled at the front by a travelling magnetic field along the track. This leads to the main advantage of LSMs - the fact that no battery needs to be placed on the track to generate the force. Coupled with the fact that the process itself is much more energy-efficient, it's no surprise that the concept is very appealing, especially the project scalability towards a fully functioning transportation method. However, the concept does come with some considerable drawbacks.

For the pod to be continuously pushed, the magnetic field must change as the pod travels. And for this to happen, we have to know where the pod is at all times. This is obviously possible, as proven by the world-renowned Japanese Shinkansen Maglev trains, but is also a considerable challenge to be implemented by a group of students. The pod would also work on more expensive tracks, as these would become the active component of the system rather than a battery in the pod.

The team is therefore making a trade-off between complexity and initial cost versus long-term cost and energy efficiency. In truth, if Hyperloop is to be implemented, it is the obvious trade to make and the team is bound to collect the fruits from their work when the propulsion and full-scale awards come rolling in. If Hyperloop is to be implemented in Europe, it would need to compete with the already extensive and mostly beloved high-speed rail network. The Delft team correctly identified that, if the student competition is true to the spirit of Hyperloop, using novel propulsion methods should be the choice.

PROSPECTS

And yet, the choice to radically differentiate themselves from the competition should not come as a surprise if you've been following Delft Hyperloop teams for a while. DH teams have always emphasized scalability, innovation, and applicability more than their competitors. A brilliant example of this is DH3's incredible interactive VR experience. At the time of writing this article, more than two months remain for teams to finalize their pods; and all the challenges that the competition conveys. The team has done an impressive job so far at building and testing their designs up until this point, and we at Leonardo Times are extremely excited to see their performance this summer.

As is the case with most Dream Teams, the members of the team will leave after the competition and make room for the next generation of talented and ambitious students. As of now, the sixth team has already been formed, and is eager to take up the mantle. If you are a student who wants to leave your mark on the future of transportation, while expanding your knowledge on engineering, manufacturing, graphic design, management, and business partnerships, Delft Hyperloop is a fantastic opportunity.

REMOTE EDUCATION

Reflecting on the effects of (prolonged) remote education

Filippo Oggioni, Roosa Joensuu, Editors Leonardo Times

TU DELFT

Students now have a strong opinion on what studying remotely means. Through a survey, we tried to gain some insight on the students' views and general concerns. In parallel, we talked to three AE Faculty representatives to find out what improvements were brought in by the Faculty.

In March 2020, when the pandemic started, universities were suddenly forced to adjust their curriculums to remote education. Definitely, no easy task. Now, after more than a year, academic institutions are slowly seeing light at the end of the tunnel, with more and more practical or collective activities allowed on campus. Nevertheless, these are strictly regulated and despite the efforts of universities worldwide, the majority of lectures are still via online platforms. We have all become experts of Zoom and Microsoft Teams; the two mythical sentences ("Can you hear me?" and "Can you give me the permission to share my screen?") have forcefully become part of every student's vocabulary. What impact does it have on students? How long is this going to last? To what extent will forms of remote education be inherent parts of higher-education curriculum? Finding answers to these questions is undoubtedly complicated. While it is safe to assume that many students have plenty to say regarding the first point, it is rather difficult to assess the other two issues without the aid of experts on higher education.
Although we are all ready to get back to normal (whatever this may mean), the Leonardo Times believes that it is important to stimulate conversation using these topics. We call it "conversation" because, in our opinion, it would be unfair to scrutinize and report the views of only a single group of people involved. The only way to conduct an honest debate about this complicated topic is to consider the views of all the possible stakeholders, ranging from students to teachers and also perhaps employers. Our aim is to give equal attention to the obvious downsides, but also to the unexpected (and often overlooked) positive implications. Due to the nature of the Leonardo Times, we specifically focused on how these issues materialized and unraveled in the Faculty of Aerospace Engineering at the Delft University of Technology.

So far, we attempted to find answers in two ways – these may not be complete, but will hopefully help stimulate a critical reflection of what has been going on. Firstly, we prepared a survey distributed among students of the faculty to get a feeling for the different opinions among students. Secondly, we talked to three representatives of the Aerospace Engineering (AE) Faculty. We have also reached out to the Internship Office, but they did not comment on remote education.

A caveat: this is a journalistic piece, not an academic article. The goal of this article is not to provide a thorough analysis of the situation and effects related to remote education, but it is simply to engage the readers in a conversation. Finally, as this is truly meant to be a conversation, we would like to hear your opinion on the topic and especially on the points addressed in this article. You can let us know by scanning the QR code at the end of the article. We also plan to publish a follow-up article with an interview with Prof. A. Kemp, former Director of Education at the AE Faculty, about what the future of higher education could look like and the role remote learning plays in it.

SURVEY RESULTS

The survey, distributed in December 2020, was aimed to gather students' views on remote education, remote internships, and future employment. Students were asked to share their experiences and give some thought to both the short-term effects - such as academic formation of students - and the long-term ones, like shaping of future professionals. The answers were collected anonymously. The survey was especially (and explicitly) directed to MSc students, but the participation of BSc students was also allowed: in total, we gathered answers from 32 MSc students and 5 BSc students. Neither the sample size and composition nor the interpretation of the survey's results is meant to constitute scientifically proven information, but merely the opinions of what we believe is a representative group of students.

In the study, students were first asked to consider what positive and negative effects remote education might have on their technical and soft skills. Most of the students pinpointed the ability to manage their own schedule as the primary positive effect of studying remotely. A third of the respondents also mentioned that the course material was easily accessible and that more supporting material is available than before. Despite acknowledging that remote education had taught them how to manage group work online, students seemed to generally think that remote education would not improve their soft skills.

The main negative consequences of studying remotely were related to the study environment. The respondents acknowledged the difficulties to focus while studying and stated that their study environments were not ideal. The majority also found the interaction with lecturers, teaching assistants, and course-mates to be more difficult. One thought-provoking result should be noted: although the primary positive aspect identified was managing one's own schedule, half of the students were struggling with time management!

Similar issues were recognized by students who had conducted a (partially) remote internship. The major setbacks during the internships were the loss of focus and problems with time management. Additionally, as communication is limited while working remotely, many reported not having experienced a sense of community. The leading benefits of remote internships were also similar to those of remote education: flexible work hours, the independence or self-management, and additionally no need to commute.

All respondents would have preferred - or would prefer - a physical internship over a remote one. The reason for this was that in an internship conducted from home, the intern misses out on getting to know the company work environment and networking with colleagues. Students mentioned their hope to "disconnect from the home atmosphere" as well.

Some respondents also admitted to being slightly worried about their future employment, mainly due to the current economic situation. Sadly, a few students seemed to be concerned that they were not well-prepared to be selected or that companies would prefer to hire people who did not study remotely. In conclusion, it seems that the flexibility that some students see as the main advantage of studying remotely or conducting a remote internship is - ironically - also its biggest disadvantage. Freedom comes with responsibilities, and finding a good work-life balance when stuck in a student room or a studio can feel overwhelming. We cannot restrain ourselves from mentioning that if you struggle with time management or if you have other concerns about your studies, you can consult the Academic Counsellors or the Career and Counselling Services. There are also online peer groups for those of you currently doing an internship or working on your thesis. For more information, please contact the Academic Counsellors of the Faculty.

Remote symposium of the DSE, the end project of the bachelor's degree.

INTERVIEW WITH REPRESENTATIVES OF THE FACULTY

What follows is a summary of an interview we had in December 2020 with three representatives of the Faculty of Aerospace Engineering: Sander Barendrecht (Head of Education and Students Affairs), Ir. Joris Melkert (Director of Education and Senior Lecturer), and Prof. Henri Werij (Dean of the AE Faculty). The full transcript of the meeting is available through the QR code at the end of the article.

We suppose the past (and current) months have been challenging for the organization of the Faculty's activities. What is/has been the most difficult task to tackle, from a practical point of view? Which were, in your opinion, the two aspects where the Aerospace Faculty was the most and least effective in providing its community with the adequate tools, methods, and guidance to successfully face this period?

SB: I think that we did quite well at the beginning of the pandemic, as we moved quite fast to remote education. Also, from the start of this academic year, we have tried to enforce the use of Microsoft Teams and have live stream lecture halls. [...] The live stream halls do have their challenges in terms of organization, but I think they are quite solid. We have learned from the springtime process that making slides with a voice-over does not really work: that is why we thought we needed to have the live stream halls - that is something we have really improved upon. [...] We have also created a Master Mentor Program: I think that was also quite solid and, although it can be improved, it was very useful to get students together. [...] Another thing that I would like to appraise is how we have been able to continue most of our projects, like the DSE: the way the DSE was carried out last year is something really commendable to our staff [...]. I am also very positive about the fact that we only had to postpone a few exams for the spring quarter, so most of our staff were able to adapt really quickly to remote education. I think the main challenge we now face, is how we can actually gain access to everybody; keeping everybody up-to-date is quite challenging. [...] The other critical thing is the very high workload, for both students and staff, also due to the extra time needed to collaborate and talk to each other online. [...]

HW: What worries me is that despite the fact that we have been quite successful in getting the bachelor students to the faculty, they are mostly students that do not know Delft at all, so the danger of falling into the isolation trap is the greatest for them. On the other hand, it is also not good that we have quite a few Master's students who are not connected to what is happening at the faculty. [...] It is difficult to figure out how to tackle that online.

JM: I think what went very well is that we - more or less - managed to act immediately when it was needed, switching between on-campus and remote teaching. We made it happen owing to flexible students and staff. [...] Very creative solutions were also found for the exams in Q3 and Q4 and the systems were reinvented quickly. [...] We made large exams possible, and we switched to non-proctored options for the exams where online proctoring was not available. People were overloaded with work, but they still managed to make the switch happen. I recall that from one day to the other I found myself teaching in front of an empty lecture room: that was strange, but we had the systems to meet this goal. We also "converted" the DSE online, so that by the end of the resit exam period in August, all exams scheduled effectively took place. Eventually, no one had to suffer any faculty-induced study delay, if they were willing to keep up, so I think that was a huge success. [...] For sure, the quality of education was not improved, although there were some brilliant ideas triggered by the situation which will probably get some follow-up in nominal times as well. The downsides and biggest worries lie in mental wellbeing, potential study delay, and increased chances for fraud. The majority of students are doing their best and not taking advantage of the situation, but we must fight against the potential of increasing fraud, because you never want to end up in a situation where you come to an employer and, looking at your graduation list, they say: "Oh, you graduated in the Corona times: I am hiring someone else because I do not trust your degree." There are a lot of positive things that we made happen, but we also have some negative aspects that worry us.

We have heard quite a lot of discussion about remote education. However, future employers and companies have not always been involved in the debate. Do you think companies have a generalized concern that current students will have an underdeveloped skillset?

HW: So far, I have not received a single indication that this is the case. To be honest, all the companies we deal with are having the same problems that we have or sometimes even bigger, certainly in the aerospace industry. We tell them how we are coping, what we are trying to do, we tell them also that we are bringing students back to campus. We try to get the practical work done, so that students develop new skills. Thus, there is no sign so far that companies would think that students now are less worthy than those who graduated before the pandemic.

JM: I actually have some positive signs. First of all, we made it possible for students first to do their thesis and then the internship. I already had employers saying: "Ah, that's nice, because when the student does well, I can immediately hire them and I don't have to wait another year for them to finish their thesis." We also have an Industrial Advisor Board that meets every six months, and this will be one of the topics on the agenda for the next meeting. In general, this situation is not ideal, but even if the quality of education might have decreased in some aspects, we are not lowering the quality of the degree: the bar is there and will remain there. In this way, getting to that level might become a bit more difficult for the students, but we do not want to run the risk mentioned above. I report a very nice fitting quote from Kevin Cowan: "Diamonds are created under very high pressure", so perhaps there are some gems being created right now. Anyway, you will get skills that the previous generation did not get, like working remotely. I guess, considering the global professional scenario in the future, this will probably become more important. This will not remove the necessity of face-to-face interaction and to get to know one another, but I think you will gain an additional skill in this sense.

SB: In the education management team, it has also been discussed and investigated to what extent the learning objectives and the final qualifications of both the BSc and the MSc programs are in jeopardy. After that inventory, there is no concern that those are in jeopardy at all. [...] At this moment, everything has been able to continue, so we think that the final qualifications of our programs can still be met.

JM: It is also important to look at the level of the program. Maybe you might see some changes in individual courses, but we have a set of different things: courses, practicals, the internship and the thesis. We look at the program level, checking that the learning objectives are met, so that we can guarantee you that the quality of your engineering degree obtained at TU Delft has the same value as before.

In the Aerospace Engineering MSc, the internship is a mandatory part of the study curriculum. For many students, remote internships are now taking place. However, this may often become very similar to a university project, with the only difference that the supervisor does not directly belong to TU Delft. With a remote internship, in particular, professional and social relationships as well as networking are minimized, causing the internship experience to lose value. What are your thoughts about this?

JM: This is of course one of our concerns. We did not want to give up the internship in our curriculum because we think it is important. You have seen that it becomes more difficult to do this online, as students miss the networking experience, but, at this point, I fear we have to face this. What we did for you is provide the possibility to easily switch the internship and thesis. We have also appointed a dedicated examiner for the internship to look at their contents and we are now opening more internship opportunities: for example, we did not allow internships at start-ups, but we are now analyzing those situations case-by-case to increase the number of opportunities available to students. We are putting extra effort in there to make the internship a fruitful professional experience in all aspects. Unfortunately, many of them (or at least a fraction of them) still have to be done remotely.

SB: We have also been looking into the number of remote internships. Our estimates show that approximately half of the internships still take place in person. The other half is conducted either partially or completely in remote settings. In addition, let us clarify: you cannot complete the internship if you are not meeting its learning objectives. You still have to develop your professional skills during the internship and the quality of internships is still being ensured by checking if the internship proposal and its conduction comply with our standards. Lowering the standards of the internship is not an option, but of course, I understand the concern about the lack of physical presence and the soft skills you refer to; for example, being unable to talk to each other at the coffee machine. This is something intangible, but it is not something that we measure through a learning objective, so I cannot estimate what the effect will be on the students.

JM: I like the remark about the internship being like a university assignment with an external supervisor. It is interesting because that gives me the indication that our assignments are realistic enough. Perhaps the topic might be different, but it is good to hear that the approach is very similar to the one used in a company. Therefore, it seems we are doing quite a good job here! [...] ✈

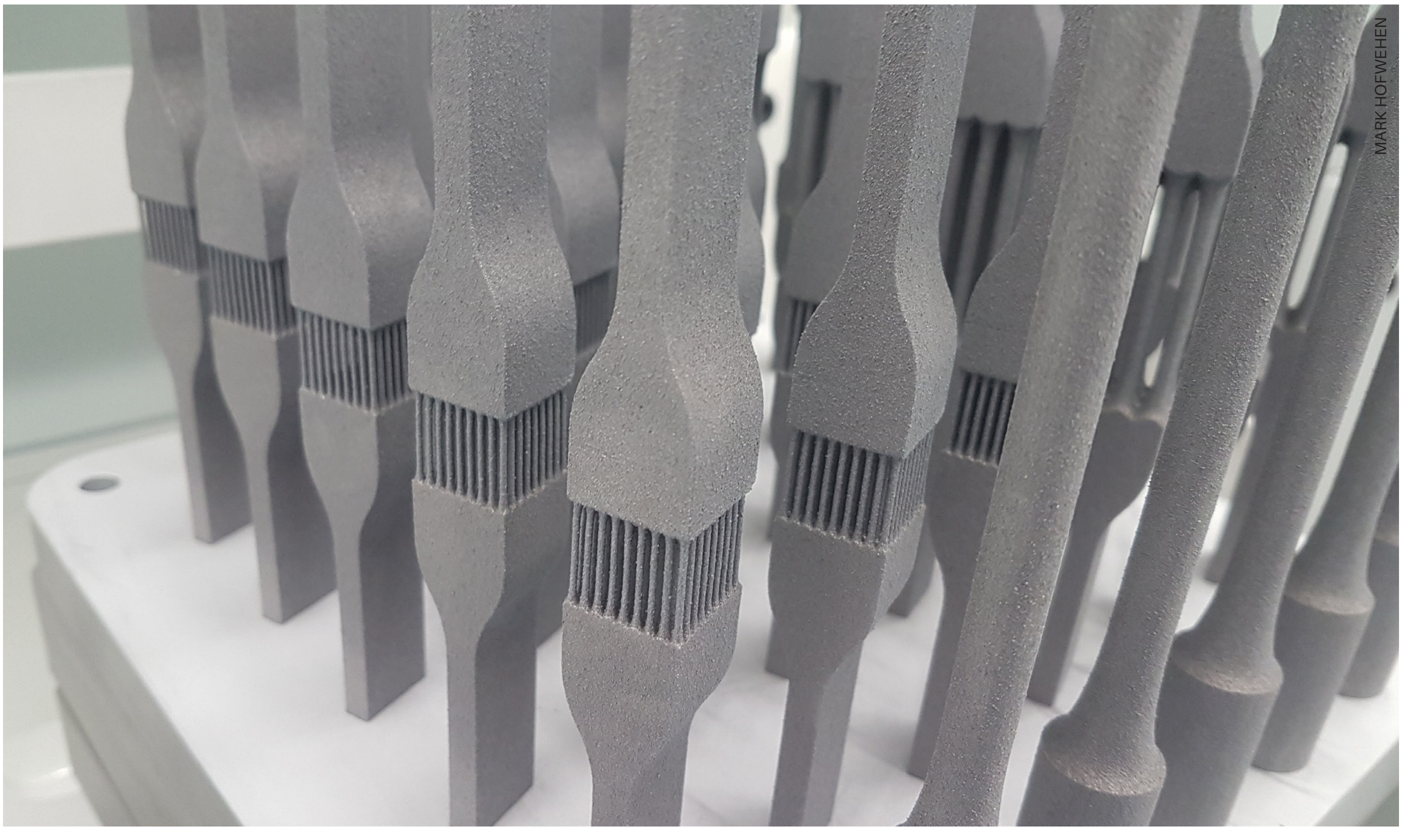
Acknowledgements: we would like to thank S. Barendrecht, Ir. J. Melkert, and Prof. H. Werij for their time. Special thanks to Naman Sadcheva for his help in planning the article.

ASM

DAMAGE TOLERANT PRINTS

Exploring damage tolerance in additive 3D-manufactured designs

Mark Hofwegen, MSc Graduate, Aerospace Structures & Materials, TU Delft



MARK HOFWEHEN

Although metal additive manufacturing is promising for the aerospace industry due to its potential to create lightweight parts, its current applications are limited. To expand its use, damage tolerance needs to be accounted for. Multiple load path structures are investigated in this study as damage tolerant alternatives to single elements.

In recent years, additive manufacturing, also known as 3D printing, has been applied in the aerospace industry to produce final metal parts [1][2]. The benefits of this technique are related to the reduction of manufacturing constraints, making it possible to create lighter and more complex-shaped parts. This leads to the possibility of further optimizing them for structural properties, meeting the challenging requirements for payload size and weight in the field of aerospace.

The flexibility offered by the various additive manufacturing techniques has led to a wide range of new design processes. These are mainly characterized by the optimization of the behavior of certain parts during loading, such as stiffness. Topological optimization processes resulting in organic-shaped parts are often mentioned when it comes to additive manufacturing. The drawback of these new processes, however, is the lack of structural integrity considerations incorporated in the process. Furthermore, the material behavior in additive manufacturing is different and less predictable compared to conventional production processes. New types of defects can be found and material properties are dependent on the thermal history during the production, leading to anisotropic properties that vary throughout a single part.

The original design framework provided by the concept of damage tolerance is thus hard to apply to these novel additive manufacturing processes. Observations show that aside from applying large design margins, structural integrity is not considered at the beginning of the design of additive manufactured parts. Therefore, the use of these parts is limited to non-critical areas of an aircraft [3]. To make use of the full potential of additive manufacturing, such as lighter parts, less scrap material and integral designs, its areas of application should be extended to more critical areas of an aircraft structure. Furthermore, the design margins should be lowered to make significant weight savings in areas of the aircraft where already highly optimized and lightweight parts are present. In order to increase the use of additive manufacturing, damage tolerant designs are needed.

MULTIPLE LOAD PATH STRUCTURES FOR DAMAGE TOLERANCE

One of the possibilities of the geometrical freedom of additive manufacturing is the use of highly redundant structures. The use of multiple load paths in the context of damage tolerance is not new, but the number of parallel load paths can be drastically increased with the use of additive manufacturing. In current applications, multiple load paths can be seen in lattice structures and optimized truss structures. These types of multiple load path

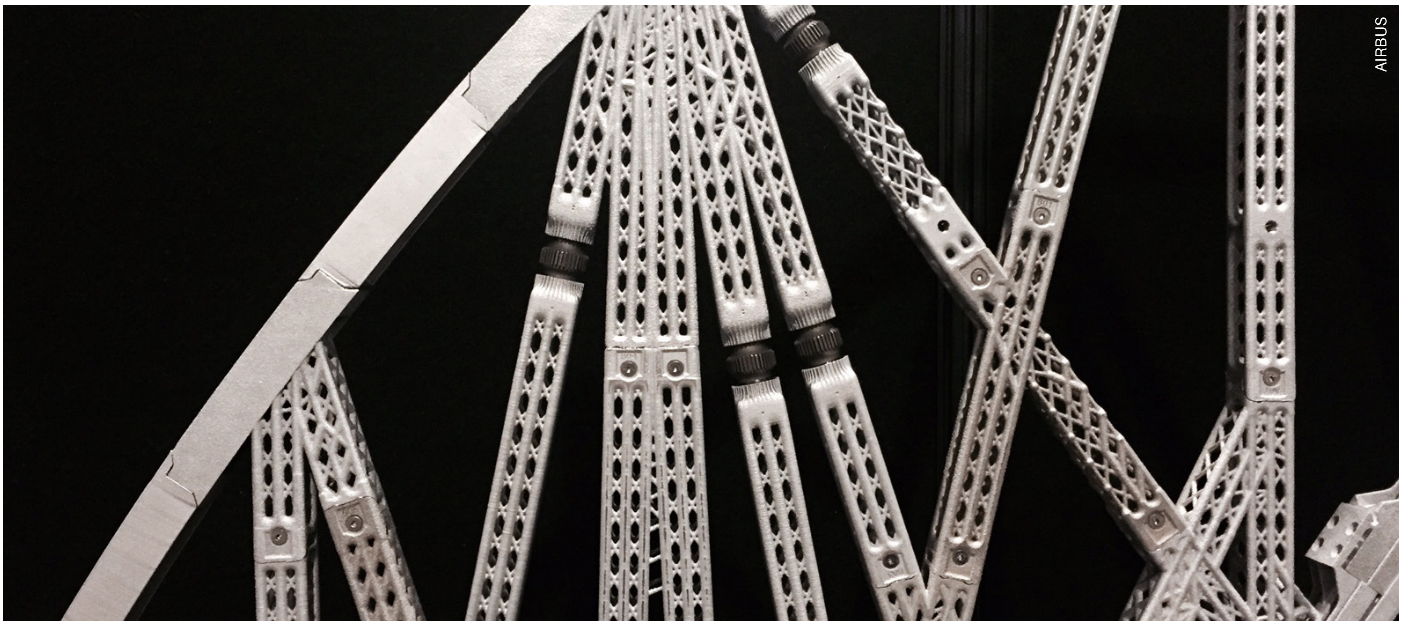


Figure 1 - Multilevel-optimized additive manufactured structure created by Airbus and Autodesk, which uses multiple load path structures inside an optimized geometry.

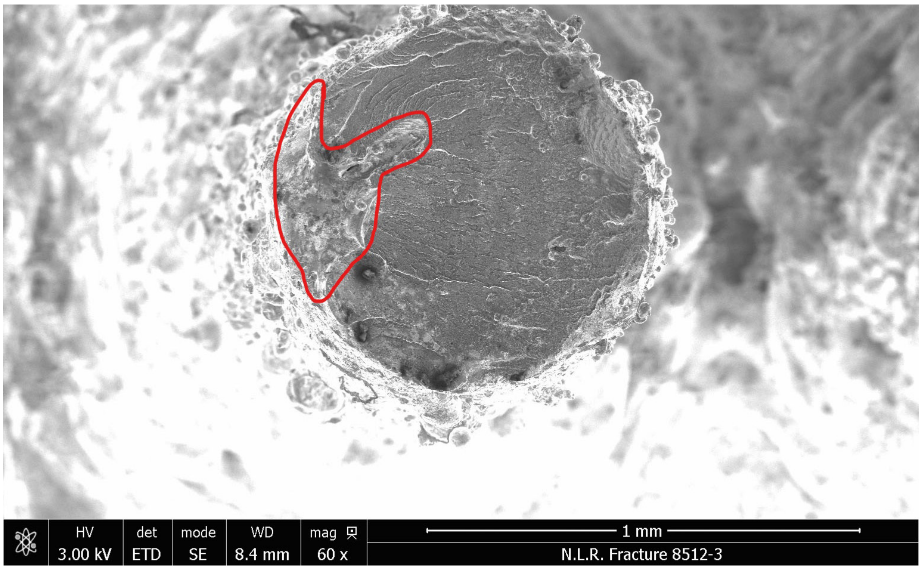


Figure 2 - Scanning electron microscope image of a 1mm strut from a multiple load path specimen. The indicated area shows a large crack initiation spot for this size struts.

structures are able to provide structural integrity through a fail-safe mechanism. Although the failure of lattices is typically described as increasingly rapid towards the overall failure of the part, modelling and testing by Burr et al. [4] proved that the period between the first element failure up to final fracture of the part can be as long as 33% of the total fatigue life. Additionally, Kotzem et al. [5] found large intervals between first and final failure, even for only six identical bars under tension-tension fatigue.

Large time gaps between the first visible part failure and the overall failure can be used to plan inspection intervals. The question, however, rises as to how long this period actually is, how it depends on the number of load paths, and whether these redundant structures are indeed a more damage tolerant alternative to single load path structures. Since the computational tools used in the optimization-driven design processes rarely provide ready-to-use geometries, designer interference in the design and multi-stage optimizations is common. The expected outcome of this concept is to apply multiple load path structures in these design steps through splitting the cross-section into multiple smaller ones.

PARALLEL STRUTS AS FIRST STEP TOWARDS DAMAGE TOLERANCE

To answer the above-mentioned questions, the fatigue life and damage propagation of multiple load path structures were investigated. This was done through an experimental approach combined with the modelling of the damage propagation. Fatigue tests were performed using structures with increasing redundancy created from an aluminum alloy (AlSi10Mg) and produced with selective laser melting. Standardized tests for these types of structures do not exist. Therefore, a new specimen, including grips to transfer the loads to the test section, was designed. The basis of this design was a standard strut geometry which was scaled according to the number of struts that were present. A set of uniaxial fatigue test specimens was designed with 1, 9, and 81 parallel struts, with varying diameters ranging from 1mm to 9mm. Verification of the design was done through a FEM analysis.

Several constraints were imposed to provide a fair comparison. Only axially loaded elements were considered. This eliminated the challenge of including bending forces and differences in local and global bending stiffnesses in the comparison. Moreover, stretch-dominant structures are generally more suitable for aerospace applications because of their higher stiffness and fatigue strength. Furthermore, the total cross-sectional area between different geometries was kept equal so that equal forces corresponded to equal stresses. To eliminate the statistical size effect in fatigue, the total outer surface area of the specimens was kept equal, resulting in varying lengths.

To research the effect of struts with different diameters, an additional set of single struts with the diameter of the 9-strut specimens were produced. As such, these could be compared with both larger diameter single struts as well as multiple load path structures consisting of the same number of struts. Finally, a small set of specimens was prepared with an initial damage to see the effect this would create in a part. The pre-damaged specimens either had a machined notch in one strut or an actual defect that was the result of the manufacturing, such as bent struts or a shear deformation in the test section.

FATIGUE BEHAVIOR

From the fatigue testing of the 64 samples in total at multiple stress levels, it became clear that the fatigue life decreases when there is an increasing number of struts of thinner diameters. The results of the single-strut specimens with varying diameters show that these differences in fatigue life mainly originate from manufacturing-related effects. Due to the varying thicknesses, parts produced from the same material and in the same batch still have different thermal histories, leading to different fatigue behavior. This is mentioned throughout literature as well. The lower fatigue life in thinner elements is attributed to the higher porosity resulting from the manufacturing [6]. From fractographical analysis with a scanning electron microscope, it was found that the fatigue crack initiation spot size is independent of the strut diameter when it comes to absolute size. The same applied to surface roughness and absolute diameter deviation from the as-designed geometry. It is well-known that the actual diameter is smaller than the as-designed geometry due to shrinkage. Caliper measurements confirmed this effect.

As a result of equal absolute deviations, the effect of these deviations is larger on thinner shaped parts, thus lowering the fatigue life. After ruling out any effects of different crack growth life and geometry deviations, this manufacturing-related size effect was shown to be the determining factor in the fatigue test results. One difference in the results with respect to the literature was that along with the diameter, the layer deposition interval time and the presence of other printed material in proximity also influence the outcome. This was shown by the testing of specimens of equal size but from different batches.

Looking at the variation of the results, it was observed that both the model and experiments showed less variation in the case of multiple struts. The standard deviation normalized to the fatigue life was used to compare the specimens. This is true when comparing the specimens with 1, 9, and 81 struts with each other, but also applies when looking at the 9-strut specimens and the individually tested single struts with the same diameter. This effect is similar to the law of large numbers. From a damage tolerance standpoint, it means that less variation is expected in the fatigue life of a part, making the lifespan more predictable if multiple load paths are applied.

DAMAGE BEHAVIOR

The failures of the individual struts within a sample were identified through the potential drop method, which relies on the increased electrical resistance of the specimen when parts crack and fail. The output of this method could be clearly connected to the audible and visible failure of the struts as observed during the test. As expected, a stepwise failure pattern was observed with a decreasing interval when more struts had failed. This is explained by the increased stress level in the remaining struts. The pattern of these failures throughout the cross-section and the height of the struts proved to be random. It indicates the stochastic nature of the fatigue failures of the struts. The numerical model used to predict the failures worked with this specific behavior. In this model, the struts were given an individual fatigue life determined by a statistical distribution. Upon iterating, the strut with the lowest number of remaining cycles was removed, after which the stress level and thus remaining fatigue lives of the other struts were updated according to Miner's rule. The predicted fatigue lives and the interval times between the strut failures indicated that the damage behavior of the multiple load path structures is well understood and is indeed a matter of statistics.

The damage behavior is quantified using the grace ratio (GR), which describes the percentage of the fatigue life where at least one strut has failed. For example, the percentual time between the first strut and overall failure. This parameter is largely determined by the number of struts present in a structure and increases with more load paths. For 81 struts, it was found that the GR is as large as 45%, independent of the stress level, whereas it is around 10% for 9 struts and zero, per definition, for single struts. With such a large period, failure of a structure is less sudden and more time for detection and repair is available.

Aside from having a larger grace period, the multiple load path structures were also less sensitive to initial damages. Tests with notches prepared in one strut and runs of the model with early failures enforced showed that an early failure leads to a larger GR and shorter overall fatigue life. The more struts are present, the less prominent this effect is. It means that the decrease in fatigue life due to a manufacturing defect or early damage is less pronounced in a multiple-load path structure. An explanation of this effect is found in the smaller stress increase upon strut failure when more struts are present.

CONCLUSIONS

For damage tolerance, the results seen in this study are promising. For multiple load path structures, fatigue life is more predictable, more time between the first visible and final failure is available, and they are less sensitive to initial damage. Aside from difficulties concerning the detection of these early failures, these positive effects are also counteracted by the shorter fatigue life of the structures with thinner struts. Although the material properties of additive manufactured parts stabilize at larger diameters [7], for the specimens used in this study a certain design case, with a given fatigue life and stress to design for, could be solved by two means: either by applying a multiple load path structure or by applying a single element with a larger safety margin. There is no better solution out of these two for all design cases. Thus, a balanced choice should be made according to the requirements of a part. Depending on the use of larger diameters and having a more stable additive manufacturing process, this conclusion might change in favor of multiple load paths in the future.

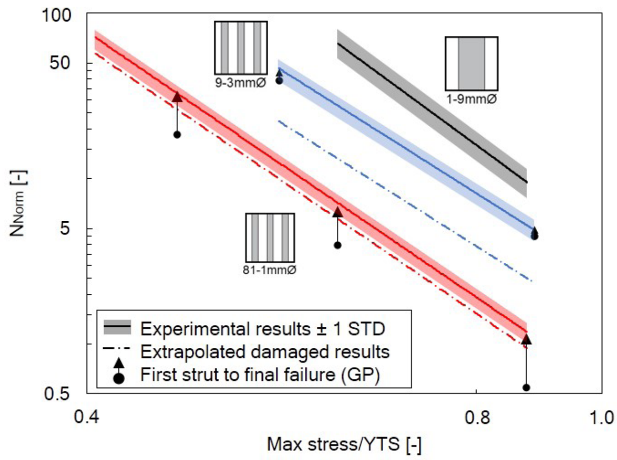


Figure 3 -Potential drop method output. The number of failed struts plotted against the normalized number of cycles for the 9-struts specimens shows that a stepwise failure pattern is present.

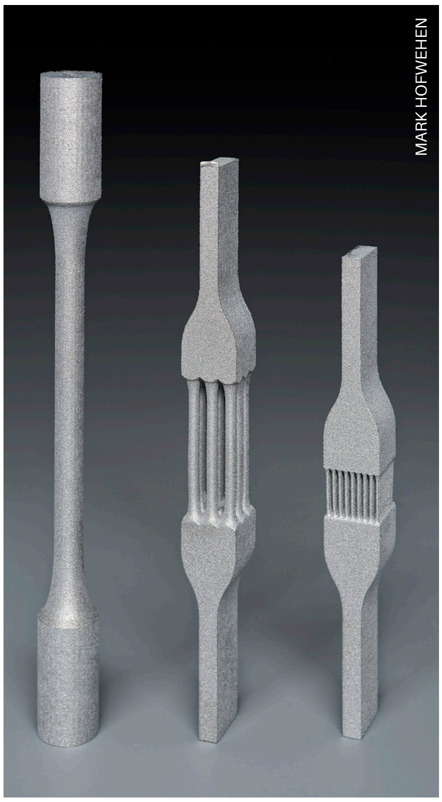


Figure 4 - Overview of specimen types used in fatigue testing.

MR. DANIEL MOCZYDLOWER

Discussions of Covid-19, sustainability and his advice to future leaders.

Naomi Lijesen & Naman Sachdeva, Editors Leonardo Times

Eve Urban Air Mobility concept.

Mr. Daniel Moczydlower is the CEO of EmbraerX, a subsidiary of Embraer, and VP of Innovation, Digital Transformation and New Business Development at Embraer. In the prequel to this article, released in the previous Leonardo Times edition, Mr. Mozydlower primarily explained the development of the Urban Air Mobility market and the role EmbraerX has within it, after its release of Eve (its electric vertical take-off and landing vehicle). As a follow up, in this interview he discussed the effect of the Covid-19 pandemic on the aviation industry and Embraer, what Embraer's strategy is for sustainability, and his personal advice for the future generation of leaders.

What is the impact of COVID-19 on Embraer and on the aviation industry?

The year 2020 was tough on the world and Embraer was no exception. The widely publicized business transaction with Boeing fell through just as the Covid-19 pandemic began wreaking havoc. In order to face it, Embraer needed to reinvent itself. I like to be optimistic and say 'never waste a good crisis', and we saw this was an opportunity to question the way things are done, decided, and processed within the company.

Sadly, like many companies, employees had to be let go, and much talent was lost. Mere months before, the globally operating company of over 18,000 employees, was reduced to functioning in a start-up fashion; with CEOs and Vice presidents physically present in meetings every day. Such small groups have the advantage of agility and trust. Decisions were processed within a day rather than a month and this responsiveness can be cultivated for the future.

Embraer's customers each experienced different levels of disruption and so they had to come together to support the communities connected to Embraer as well. In Embraer's home country Brazil, the Air Force became the front-line responder for the crisis and was heavily relied on for transporting health care and personnel, like in many other countries. Furthermore, the company deployed

executive jets to make humanitarian flights, as in some cases these were the only ones permitted to fly. Also, due to the massive disruption in the international supply chains, it was predicted there would be a shortage of ventilators in Brazil. To aid this, parts for the ventilators were manufactured in Embraer's facilities. Additionally, Embraer teamed up with hospitals in Brazil to analyze a start-up's design for a mobile intensive care unit, which could be set up in clinics that lacked infrastructure. These efforts continued in parallel whilst trying to protect the company and supporting the customers like airlines and Armed Forces.

The Covid-19 pandemic has been arguably the most serious crisis the aviation industry has ever faced. Though many analysts attempt to predict the shape of the recovery, there is no single answer to this question. Mr. Moczydlower believes it will play out differently for the segments of the industry (i.e. the different market niches, sections and regions of the world).

For the military/defense section there was no slow down. If anything, the pace of the industry picked up. This is because the Armed Forces are not only needed in times of war but are crucial in moments when the country faces humanitarian crises. Thus, the defense section needed to step up and be well equipped to aid their countries. Consequently, even in the midst of the crisis, Embraer announced an important sale of two KC-390 Millennium aircraft with the Hungarian Government, our second NATO customer. This aircraft series continues to gain interest and traction with other NATO countries, particularly in Europe. With its main competitor designed 40 years ago, the Millennium series provides the latest generation technology, ideal for military transport and humanitarian missions as proven in its vital role in Brazil during the COVID-19 pandemic.

In the executive jets and business aviation section, there was a strong peak in interest during this period. Many individuals who previously relied on the business class of commercial aviation are now turning to private jet options, whether it be ownership or executive jet flights provided by companies such as Flexjet or Netjets. So, although there was an initial impact in the beginning of the crisis, the comeback was determined and quick.

However, as foreseen, it was the commercial aviation sector on which the pandemic was most destructive and which will likely have the longest recovery. When looking within commercial aviation, it's clear and expected that the long-haul and international flight segments were, and continue to be, hit the hardest. Currently, many countries rightly still have travel bans and it's likely that this will take many months before the situations improve enough to ease off these restrictions. And when they do, there is still much fear surrounding the prospect of bundling into aircraft even with strict health protocols. Yet, as vaccination rates improve, this segment can make its resurrection. It may not be back-to-normal, because so much of normal life has been altered due to COVID-19. For example, it can be predicted that business travel may diminish due to business meetings now being successfully conducted on digital video call platforms rather than in physical conference rooms. Though of course, in certain cases, eventually, physical meetings are necessary, and so this may also drive its slow return. As for leisure travel, it can be described as a 'positive timebomb'. After being cooped up for so long watching the pandemic dominate the world news day-in and day-out, people are desperate to travel, to get away, to return home, to embrace loved ones or probably even escape them. As the vaccination process progresses, it can be expected that there will be a boom in travel following this difficult period.

For Embraer, the sweet spot of the aviation industry has always been the domestic/regional sector. In countries such as the US and even Brazil, the level of recovery in domestic flights is not at the pre-crisis level but still quite impressive. Consequently, companies that typically don't operate regional jets are now looking into them as options to gain flexibility in their fleet strategies. This holds much potential for Embraer and its E-jets, particularly the E2 family which is very competitive in its fuel efficiency, comfort, and latest generation fly-by-wire technology. The factor of geography is very noteworthy in its effect on the regional aviation sector. Countries implementing responsible precautions are recovering much faster than others that may not have applied these so quickly, and so the number of domestic flights there can increase more rapidly.

Embraer surely has the advantage of covering the defense sector, the executive jet sector, and the commercial sector (and happens to focus in the most quickly recovering segment of this sector). This already puts it in a good position in terms of recovery from the crisis. When this is factored in with the agility and lessons learned from the new way the company had to function, it is reasonable thatwe are 'cautiously optimisitc'. Embraer is hopeful to bring back the talent that was let go last year as well as gaining new talent and new insights learned from this crisis.

What is Embraer's strategy towards sustainability, especially when regional flights are susceptible to 'flight shaming'?
This is a very important topic for Embraer and the whole aerospace industry has already committed to emission reduction a long time ago. There is a global shift to renewable energy even from big industrial economies like the US and China, and we believe that the change is coming faster than predicted. Almost 75% of all new additions in power generation in 2019 globally are renewables. Europe's more than 50% power is being generated from renewables. In Norway, more electric cars have been sold than conventional cars and General Motors is soon going to stop the production of its internal combustion engines. This proves that the renewable energy revolution is already here.

All the other sectors are moving forward and even if today, aviation's share in global emissions is only 2-3%, it can dramatically increase if the sector does not move faster towards sustainability. However, this transition has to be systematic. The first step to transition should be the fleet replacement and Embraer is very well positioned in this segment. Embraer's latest aircrafts offer 15-20% reduction in fuel consumption compared to its predecessors.

The second step is to research new technologies. There are currently many technologies available like Sustainable Aviation Fuels (SAF) which are certified and can be used to reduce emissions. Multiple airlines are using it but there is a need for disruptive innovation in the production of SAF as the current production cost is very high. Other technologies like hydrogen or battery hybrid propulsion could change the aerospace industry significantly. Renewable energy alternatives will reduce operation costs and make aviation much more accessible to the general public.

We believe that the aviation industry is on the verge of the biggest revolution since its dawn and it is an incredible time to be part of this change. Furthermore, he added that the revolution will start from the smaller aircraft, especially Urban Air Mobility (UAM). It is not a coincidence that the biggest investment funds in the world are investing in UAM when the industry is transitioning towards renewables. The transition is technologically possible and battery technology will play a big role in it. Once the technology is proved within the UAM, then it will have sustained growth in commercial aviation, especially the regional market, which is Embraer's strength.

What lesson would you give to the younger generation who want to be future leaders?
One of the biggest lessons to become a good leader is to be humble. Often people feel that if they show their weaknesses, show their vulnerabilities to their teammates or their subordinates, it will have a bad impact

EMBRAER

on their image. Hence, they always pose themselves as this highly self-sufficient person who can do anything. This is often a mistake. Most of the people who have this perspective have a very hard time learning from others. Everyone you meet has the potential to teach something new if you are open to learning. There is so much diversity in people's perspectives and it is very important as a leader to respect them and analyze them to make better decisions. In the end, we all are humans, we make mistakes and we are vulnerable. Accepting it makes us stronger and helps in building a learning attitude.

Another lesson is to believe in yourself and prepare yourself for the opportunities which might arrive at your doorstep. Luck is a big factor when it comes to a successful career and you have no control over it. But what you can do is to prepare yourself for any opportunity that might come and be ready for it. There are multiple roles for which which I was not ready in my career, but I took them them as a challenge and tried to learn from my superiors who were much more knowledgeable and experienced.

The third lesson would be to build a very diverse but effective network. Build real connections with people and be open to listen to them and learn from them.

The fourth and most important is to build trust. I believe trust can be mathematically defined as follows:

$$\frac{Credibility \times Reliability \times Intimacy}{Self\ Assurance}$$

You should never let your self-assurance be too high because it limits your ability to learn and to be humble towards others.

Lastly, a good leader should be the one who is reachable and listens to his/her team's problems and feedback. It's my vision to make the executive team of Embraer's executive team more reachable to its employees and bring innovation in the company using the bottom-up approach.

We, at Leonardo Times, would like to thank Mr. Daniel Moczydlower for, once again, taking time from his busy schedule to talk to us. His enthusiasm and openness with answering our questions was greatly appreciated and his responses were thoroughly enjoyed. We would also like to also thank Ms. Christiane De Vilhena Santoro Ukita Bonamini for helping us in organizing this interview. ✈

SUSTAINABLE STUDIES

Interview with the Green Team AE

Roosa Joensuu, Editor Leonardo Times

TU DELFT

The student organization Green TU is working towards integrating sustainability into all university affairs. The faculties have Green Teams, introducing green values into education. In the Faculty of Aerospace Engineering, the Green Team was established in 2020. The current members work on four portfolios: faculty operations, bachelor education, master education and social engagement.

Can we start with some brief introductions, and maybe a fun fact about yourselves?

Aïcha van Veen: I finished my bachelor's in Aerospace Engineering last January, and next September I will be starting my master's degree, hopefully in the Space Flight track. I am the chairperson of the Green Team, responsible for bachelor education tasks, social engagement and awareness. A fun fact about me is that I love Christmas! I have a Christmas tree permanently in my room.

Cristina Riti: I am a first-year master student in Space Exploration, and the secretary of the Green Team. Thus, I keep our email inbox up to date, and write the minutes of the meetings. I am also dedicated to the operations portfolio, which generally deals with the practical side of making the faculty of Aerospace Engineering more sustainable. A fun or strange fact about me is that I really enjoy everything related to the medieval times. I read a lot of fantasy books and medieval epic cycles.

Rick Nelen: I am doing my master's in Flight Performance. Last year I was a part of the Eco-Runner dream team, where I was responsible for aerodynamics. For the Green Team I am working on the master education portfolio, which means that I look into how we can improve the implementation of sustainability in the master tracks. My fun fact: I went to Australia for my minor, and after my studies I went on a road trip there - so now I have driven more in Australia than in the Netherlands.

Kiva McSorley: I study manufacturing within the Aerospace Structures and Materials track. In the Green Team I pair with Aïcha. We work together on bachelor education and social engagement. We were equally interested in these two portfolios. Our main responsibilities include; to try to incorporate sustainability into the bachelor program, and bring awareness of sustainability to the faculty students and staff through social media and other means. My fun fact is that I have sailed from the Canary Islands to the Caribbean in a group of four.

Why should sustainability issues gain more attention in the faculty and why is sustainability relevant to the studies of Aerospace Engineering?

Aïcha: Sustainability really is our future: we need to live sustainably now to keep doing the same things that we do today in the future. That is also the case for the aviation industry. If we want to be sustainable and as successful as possible, we need to incorporate this into our studies. We need to learn how to apply it to engineering. Thus, how to design sustainably. This is why I think it should gain more attention within the faculty.

Rick: The issue we are facing is that aviation is one of the few sectors where there are limited resources to counteract the effects of global warming at the moment. The industry, aside from Covid-19, is growing rapidly, and therefore the impact on the climate is increasing. That is something that we have to prevent sooner rather than later.

Cristina: As engineers we cannot study aircraft and learn about the technical aspects without considering the surrounding world in which we live. We also need to take into account all the social aspects. Sustainability is one of the most important topics, because, as Aïcha said, without sustainability there is no future for us - Not only for the aerospace industry, but for the whole of humanity. Also, I think that the space industry is often seen as an area, where it is less important to think about sustainability. However, space travel uses and offers resources for everyone. This is something that we need to respect. We should not pollute in space either.

Kiva: In my understanding of engineering in general, but particularly aerospace engineering, we are always designing for the future. We know that our design of airplanes or rockets will last several years or decades. Yet, we also know that the design process takes a certain amount of time. Therefore, at the time of implementation, we should already think about the future. As mentioned earlier, the future is sustainable or there will be no future. This is why we should incorporate it more into the study. I agree with Cristina, I think it is our responsibility as engineers to design a future that is survivable for us as humanity.

The GreenTeam of Aerospace Engineering, from left to right: Cristina Riti, Kiva McSorley, Rick Nelen and Aïcha van Veen.

What are the current projects within the operations portfolio to improve sustainability within the faculty?

Cristina: Within the faculty we tackle different practical aspects, for example, from food to waste separation. Right now, we are working on a plan for student and staff mobility with the sustainability coordinator of the university, Andy van den Dobbelsteen. We want to focus on finding ways to increase the use of public transport for both commuting and business trips, so that we can cut down the CO_2 emissions of the faculty.

How was sustainability addressed in the bachelor program? How are you working towards increasing sustainability topics within the course?

Aïcha: In my opinion, there is not much sustainability in the curriculum yet. Hence, our goal is to increase this in courses and projects. We gave a sustainability workshop in the 'Design and Construction' project of the first-year students, so it can be included in their literature study and in the design of the wing box structure. That was the first step taken to include sustainability more in the curriculum. Now we are going to continue to collaborate with the professors and lecturers to make sure that sustainability does become a more significant element in the bachelor program.

Kiva: We never had a specific class on sustainability, it was only briefly introduced in certain areas as a topic of consideration. In the 'Design Synthesis Exercise', the bachelor thesis project, we had to design for sustainability, but we were not given the tools to do it. The previous Green Team already started incorporating sustainability into the 'Design and Construction' project with the project leader Ir. M.J. Schuurman, and he made changes. Now, we would like to incorporate sustainability to the other projects as well. Ideally, in the long-term, it would be nice to have a course dedicated to sustainability.

Is the situation different in the master's degree program? What are your short- and long-term goals towards more sustainability?

Rick: In the master program, it is a bit different than in the bachelor's; there is quite a lot of variation between the tracks. In Control and Operations for example, there are several courses related to sustainability, in the other tracks less so. This is one of the things I want to address: making sustainability more broadly available to master students. We are looking into different options for the entire master, and apart from that we are considering individual courses and how topics related to sustainability are addressed. I am also working on an overview with more accessible information about sustainability, which could help students choose their courses. My short-term goal is to get more sustainability and life cycle assessment into one specific course - Manufacturing of Aerospace Structures and Materials, starting next

GREENTEAM AE

September.

What do you think the future of our faculty and aerospace engineering as a study will look like?

Aïcha: I think there will be some changes. I believe that we can have a great impact on the study and the faculty, because people realize that sustainability issues are something that they need to act upon. Sometimes they do not know how, or they just need a little push, and we are there to give that push. This is only the second year of the Green Team in our faculty, and we have already achieved many things. I think that there is a great future for our faculty and our study.

Rick: I think we will definitely help the faculty. The faculty is already involved in sustainable projects, such as the Flying V, and the students should experience this progress too.

Cristina: I would like to see a bigger Space Flight track, because now there is a limited number of students who can enter. We could also have more collaboration with other faculties. For example, the Space Track could gain from collaboration with studies such as Applied Sciences. I believe that in the future the boundaries of each faculty are going to merge a little - of course I do not know this for sure.

Kiva: Unrelated to sustainability, I see that in our faculty, communication between professors and students is increasing. I hope that this will also reflect on sustainability, so that there could be more open discourse on it. I would like to see students meet up to discuss topics like sustainability, and novel innovations related to engineering. During the bachelor's it was not really done that much. Additionally, I would like to see the faculty canteen going vegetarian.

What improvements with respect to sustainability do you currently see in the aerospace sector and what still needs to change?

Rick: First of all, we have the issues caused by burning kerosene. There are now very promising ideas of using, for example, hydrogen as a fuel. It is a great step forward, but at the same time we must realize that the emissions from aviation are not limited to CO_2. With hydrogen there is no CO_2 and there is less NO_x, but it produces more water vapour, which also contributes to global warming. We should include the effects that different design options have during their lifetime in the decision-making of the design process. We should also ensure that at the end of an aircraft's operational life, most of its parts are recyclable. With all the start-ups evolving and the competition they create, it could be interesting to see a decrease in the time involved between the design and development from the start of programme to the introduction of a new aircraft.

Aïcha: About recycling of aircraft parts at the end of its operational life, that Rick mentioned, you can already see this developing in the aviation industry, but I feel it could be improved upon further. There are many ways in which you can make the end-of-life steps more sustainable. We should look at full life cycle assessments - there is so much room for improvement in so many aspects, from manufacturing to operations, and to end-of-life.

Cristina: In terms of space, I would like to see more international regulations on space debris and the number of satellites that private companies can put into space. I would also like to see more media attention on the research that has been done, and that will be done, in the field of Earth observation. All of this research has been so important for our current understanding of climate change. Sometimes when people think about space, they only think about people going to the Moon or Mars, and these things do seem less important now that we have to worry about sustainability and climate change. What we do not see as much is how the space industry is also working on those topics. It should be discussed more in public media. Of course, the Earth observation missions should also continue!

Kiva: In general, the aerospace industry, like other industries, is pushing for constant growth. This needs to change. In aviation, I think we cannot always push towards growing more and more. Sometimes, we need to just improve what is already there. It is inherently unsustainable to think that our world with its limited resources could function to support unlimited growth. Concerning the space industry, I suppose the universe is vast and therefore not exactly resource-limited, but we are not able to reach these resources yet. It would be worth slowing down the growth and focusing on what is happening at this moment, to ensure a sustainable future. ✈

LT would like to thank the Green Team for the conversation and insights into their work.

TUDelft GreenAE

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